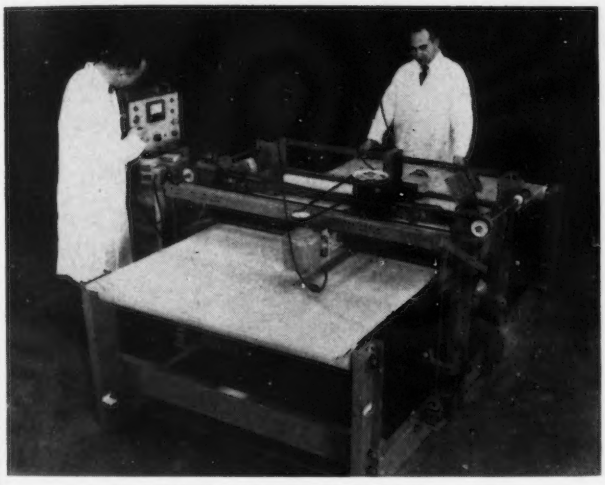
Forest Products Journal

Attend Your Nearby FPRS Section Meeting This Fall—p. 5-A

Vol. 15, No. 8 August, 1965



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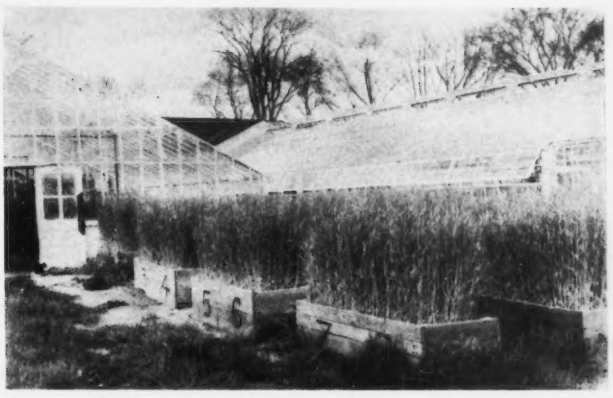

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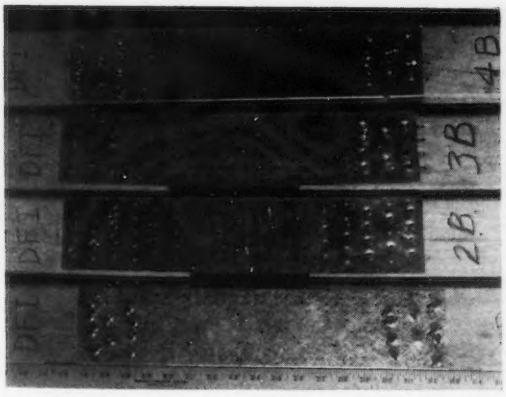

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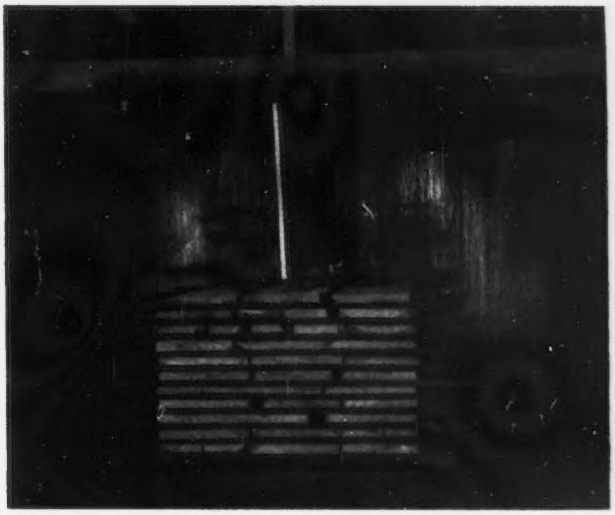

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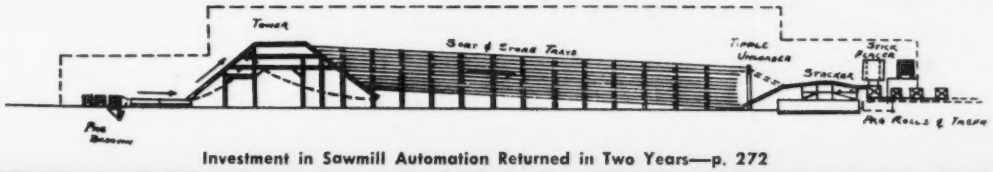

Investment in Sawmill Automation Returned in Two Years—p. 272

Published by the FOREST PRODUCTS RESEARCH SOCIETY BOX 2010 MADISON 5, WISCONSIN

WHERE'S THE GLUE LINE? *With new* MELURAC® *260 splicer glue* – product of Cyanamid adhesive research – splices disappear in light or dark veneer! A hint of nutshell flour gives a faint tan tint that blends with any wood. Faster curing means lower temperature splicer bars with no risk of scorching. Add only water – catalyst is incorporated. You have three to four days assembly time, very good spreading, very good washing. Or, if you don't mind adding a hardener, try nonstaining MELURAC 255. In either case, expect *invisibly* perfect results!

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FOREST PRODUCTS JOURNAL

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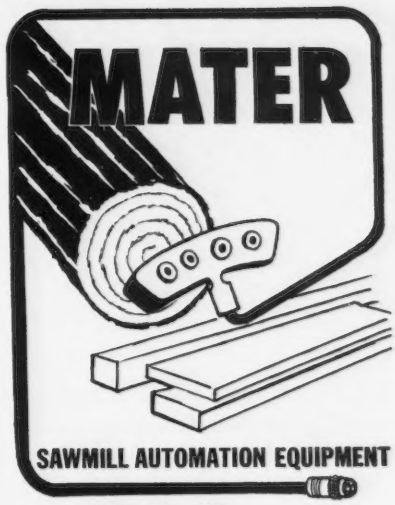

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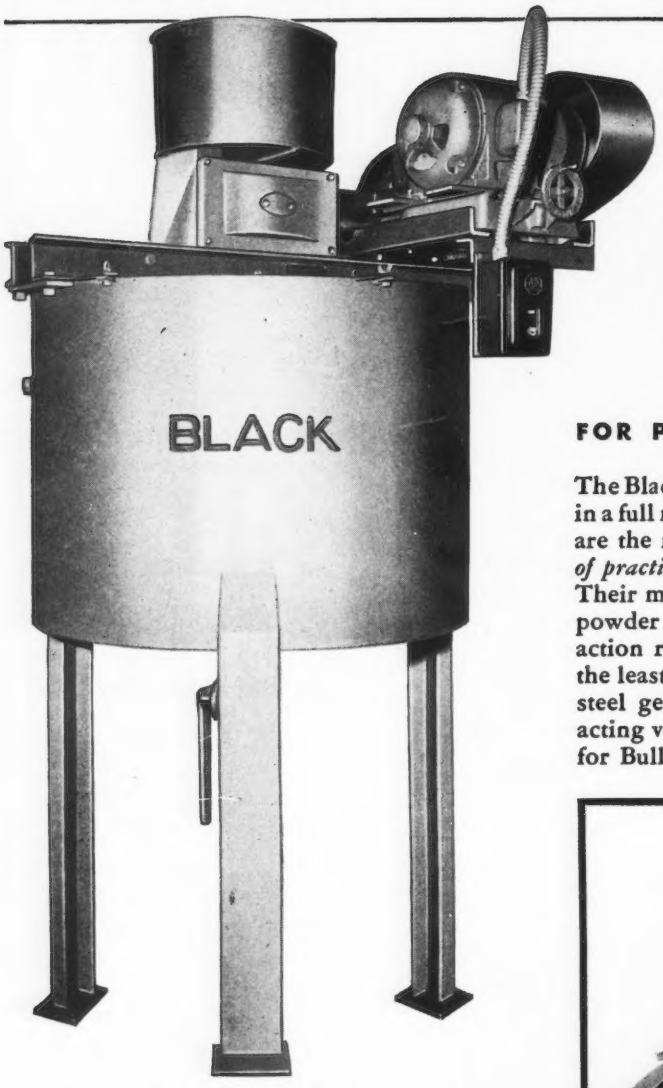


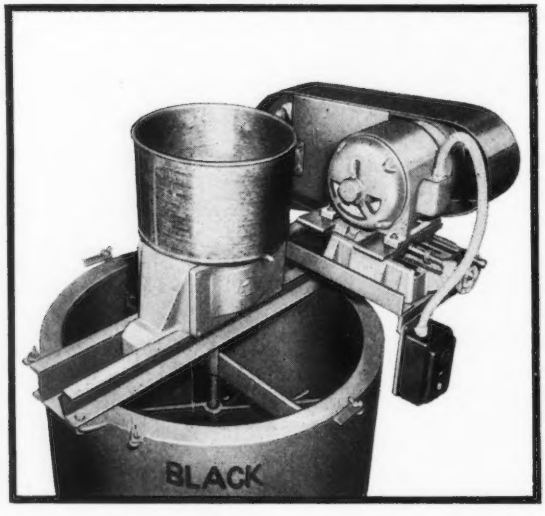
Cold glue MIXERS

FOR POWDERED OR LIQUID ADHESIVES

The Black Brothers stationary cold glue mixers are made in a full range of capacities from 10 to 500 gallons. They are the result of *expert engineering combined with years of practical experience in glue equipment manufacturing.* Their many special features include: (1) Sifter for glue powder (2) Double agitators which give a beating action resulting in the smoothest possible mixture in the least possible time (3) Pressure lubrication (4) Cut steel gears . . . hardened and lapped (5) Large quick-acting valve at bottom. For full information write today for Bulletin 11-I.

TWO-WAY AGITATION ▶

To the right is a partial view of a 60 gallon cold glue mixer arranged with a variable speed drive and water jacket. The covers have been removed showing accessibility for cleaning, and also the double agitator arrangement. Note the thick double walled tank permitting free circulation of water for cooling the glue batch.



PORTABLE MOTOR DRIVEN GLUE MIXER ▶

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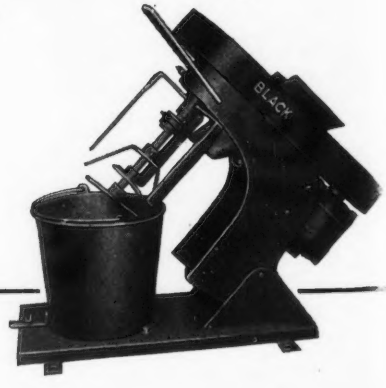

"If It Is Gluing Equipment — We Have It"

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GREENLEE machines help White FURNITURE CO. maintain heirloom quality and high production...

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They are particularly pleased with the success they have had in cutting *solid* hardwood serpentine drawer fronts for the beautiful French Provincial Dresser at the right. This work is done on a Greenlee No. 545 Double-End Tenoner equipped with a dado attachment and lathe type cutterheads. The stock shown in the photo above is approximately 7½" wide by 36½" long. The company states that it could not achieve the same excellent production rate and smooth finish by any other means of machining.

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Plan to Attend FPRS North-Central Region Meeting in Chicago, Nov. 5 & 6

L. to R. Bob Archambeault, Midwest Section Chairman; Don Lubeck, Program Chmn.; Joe Allegretti, General Chairman.

Theme: "Interior Finishing of *All* Wood Products—from Insulation Board through Furniture"

Nov. 5—*Accepted and New Methods of Finishing*, including Airless spray; Roller coating; pressure curtain coaters; Automatic spraying; Dip and flow coating; Controlled temperature, low pressure and catalyst spraying. Plus . . . One hour discussion period; and traditional "Paul Bunyan" hour.

Nov. 6—*Preparation for Finishing*—including proper sanding techniques; supplemental equipment; new machinery, conveyors, etc. Plus . . . Official luncheon.

Dates: Nov. 5 and 6. **Place:** Conrad Hilton Hotel, Chicago. **Registration Fee:** $5.

Cooperating Sections: Midwest; Upper Mississippi; Ohio Valley; and Great Lakes.

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WOOD TREATING

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FPRS News-Digest

Nine FPRS Sections to Hold Meetings this Fall

Great Lakes Section to Meet Oct. 6 and 7

"Merchandising of Lumber and Wood Products," a program jointly developed between FPRS Great Lakes Section, and FPRS National Merchandising Division, under the chairmanship of Wm. B. Lloyd, Michigan State University, will be presented Oct. 6 and 7 at the Fort Shelby Hotel, Detroit, Michigan. Registration will begin at 8:00 a.m., Tuesday.

PROGRAM, Tuesday, Oct. 6

Chairman—S. W. Tamminga, Vice Pres., Hekman Furniture Co., Grand Rapids

9:30 a.m.—Welcome—Dr. E. S. Harrar, Pres., Forest Products Research Society

9:45 a.m.—"The NLMA National Wood Promotion Campaign—B. C. Hartung, Director of Member Relations National Lumber Mfgs. Assoc., Washington, D. C.

10:30 a.m.—"That Material—Wood—Let's Merchandise it"—Speaker Pending

12:30 p.m.—Luncheon
Chairman—Everett Ellis, Assoc. Prof., Wood Technology, University of Mich.

1:30 p.m.—"Prefabrication—The Retailers Secret Weapon"—Louis E. Legg, Jr., Pres. Lansing Lumber Company, Lansing, Michigan

2:45 p.m.—"The Wood Window! On the Rebound"—Ralph Pauley, President Dayton-Akron Sash & Door Company, Dayton, Ohio

4:00 p.m.—"The Wood School! At Last"—Dr. John L. Hill, Technical Promotion, NLMA.

7:00 p.m.—Paul Bunyan Nite

PROGRAM, Wednesday, October 7

Chairman—H. Garland, Director, Forest Products Research Division Michigan College of Mining & Technology

9:30 a.m.—"The Laminated Beam Boom"—Elon E. Ellis, Vice President, Timber Structures, Inc. Portland, Oregon

10:15 a.m.—"The Madam Asks for Wood Kitchen Cabinets"—National Institute of Wood Kitchen Cabinets, Chicago, Illinois

11:00 a.m.—"The Lumberman Behind the Metal Desk"—Speaker Pending

12:30 p.m.—Luncheon
Chairman—Jack D. Skriden, Metropolitan Lumber Co., Royal Oak, Michigan

1:45 p.m.—"Wood that doesn't Burn"—S. W. Anthony, Koppers Co., Pittsburgh, Pa.

3:00 p.m.—Panel—Moderator—Wm. B. Lloyd, Assoc. Prof., Michigan State University "Where are We (the lumber industry) Going?" Panelists: Retailer; Wholesaler; Millwork Jobber; Residential Builder; Lumber Manufacturer; Architect.

Ohio Valley Section to Meet Oct. 8, 9 in Chillicothe, O.

The Ohio Valley Section fall meeting will be held at the Elks Club on Thursday P.M., October 8 and at the Recreation Hall, Federal Reformatory, Chillicothe, Ohio, Friday P.M., October 9.

Program:

"New Developments in Machine Sanding" moderated by Henry Espel, Baldwin Piano Co.

"New Wood Finishes. What are the Latest Developments in Poly Vinyl, Poly Ester and other new Finishes?" moderated by Sterling Durst, Gamble Bros.

Report on N.A.F.M. Tour of European wood working plants. European methods, equipment and material utilization. Paul Fenn, chairman, and other speakers from tour personnel.

"Future of Hardwoods" moderated by Dr. Carl Trinkle. Dr. E. S. Harrar, National President of FPRS is hoped to be the speaker.

Important FPRS Dates

October 6–7, 1959: Great Lakes Section Meeting, Detroit, Michigan.
October 8–9, 1959: Ohio Valley Section Meeting, Chillicothe, Ohio.
October 9, 1959: Northern California Section Meeting, Santa Rosa, Calif.
October 11, 12 and 13, 1959: Mid-South Section Meeting, Beaumont, Texas.
October 23, 1959: Rocky Mountain Section Meeting, Denver, Colorado.
October 29–30, 1959: Northeast Section Meeting, Worcester, Massachusetts.
November 5–6, 1959: North Central Regional Meeting, Chicago, Illinois.
November 12–13, 1959: Carolina–Chesapeake Section Meeting, Hickory, N. C.
December 3–4, 1959: Southeastern Section Meeting, Daytona Beach, Florida.
June 5–9, 1960: Fourteenth National Meeting, Quebec, Canada.

No. California Section to Meet at Santa Rosa, Oct. 9

The fall meeting of the recent host section to the national meeting will be held the afternoon and evening of Oct. 9, at Santa Rosa. Plant tours will be conducted to the Fluor Products Co., and the California Wood Products Co. The evening will be devoted to dinner and a speaker to be announced.

Come to Texas, Oct. 11, 12 and 13

Plans for FPRS Mid-South Section's 11th Annual Meeting, to be held at the Ridgewood Motor Hotel, Beaumont, Texas, Oct. 11, 12, 13, are well-underway according to Section Secretary, Paul Kramer, Texas Forest Service.

A "Welcome to Texas" party is scheduled for Sunday evening; a full day of technical sessions Monday, and several outstanding plant tours on Tuesday morning.

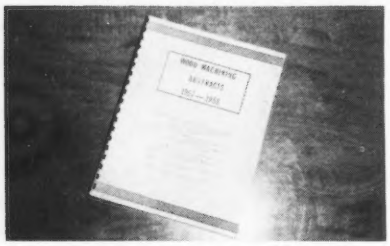
Wood utilization plants to be toured include: the Kirby sawmill at Silsbee; and the new East Texas Pulp and Paper Co. at Evadale.

Rocky Mountain Section to Meet at Denver, Oct. 23

FPRS' smallest and one of its most progressive sections, under the able direction of chairman Bob Bader, Denver, is planning a program of varied interest to local wood industries, in Denver, Oct. 23. The morning program will be devoted to papers and discussion of methods of wood fire-retardant treatment. The guest speaker, on research broadly, is Dr. Fred Dickinson, Director of the California Forest Products Lab., and FPRS Southwest Region board member.

Reporting on an earlier Section meeting held May 28, Secretary Phil Opsal, Colorado State College, advised that 25 guests, including 18 students, visited the famous Shwayder Bros. (Samsonite luggage), Fibreboard Paper Products, Western Wood Excelsior, Bord, Inc., and Veritcel Co. plants.

DIVISION *Views and News*



FPRS Wood Machining Abstracts 1957–1958

The Committee on recent wood machinging literature, a sub-division of the Wood Machining Division, has compiled a 20 page report containing significant abstracts selected from world sources on the subject of wood machining. The purpose of these abstracts is to supply information whereby one may locate recent publications in the field. Section 1 contains a partial list of sources on wood machining subjects. Section 2 contains abstracts grouped by the general subject matter. The Committee is composed of: Charles W. McMillin, American Machine & Foundry Co. Robert J. Hoyle, Potlatch Forests, Inc. Norman C. Franz, University of Michigan. Lawrence Leney, University of Missouri. Richard Perkins, Syracuse University. Single copies are available on request to: Forest Products Research Society, Box 2010, University Station, Madison, Wisconsin. Additional copies are available at 50¢ each.

BUSINESS TRENDS

FPRS–U. OF WISCONSIN ADHESIVES MEETING

Engineering institutes in cooperation with the glues and gluing division of Forest Products Research Society and the Forest Products Laboratory announces that its institute "Industrial Adhesives Applications" will take place on Thursday and Friday, October 1 and 2, 1959.

PROGRAM

Thursday, Oct. 1, 8:30 A. M.

Registration—Wisconsin Center Bldg., Madison, Wisconsin

A. M.

9:15—Introduction, Presiding Chairman Richard F. Blomquist, U. S. Forest Products Lab., Madison, Wis.

10:40—Designing With Adhesives: A. J. Slosser, Armstrong Cork Co., Lancaster, Penn.

11:45—Lunch

P. M.

12:45—Adhesives in the Wood and Paper Industries.

1. Plywood and Doors: Leonard A. Ropella, Tech. Dir., Roddis Plywood Corp., Marshfield, Wisconsin
2. Structural Glued Laminated Timber Adhesives: Maurice J. Rhude, Chief Eng., Unit Structures, Inc., Peshtigo, Wis.
3. Adhesives in the Housing Industry: Willard Worth, Tech. Dir. National Homes Corp., Lafayette, Indiana
4. Adhesives Used for Particle Board Manufacture: John W. Maxwell, Manager Technical Service, Resins and Chemicals Dept., The Borden Chemical Co., New York, N. Y.
5. Paper and Fiberboard Adhesive Applications: Richard E. Smith, V. P. for Research and Development, H. B. Fuller Co., St. Paul, Minnesota

2:45—Panel Discussion

6:30—Dinner, The Hoffman House

Friday, Oct. 2

Presiding—Robert Stedfeld, Associate Managing Editor, Machine Design, Cleveland, Ohio

A. M.

8:30—Adhesive Fabrication of Metals and Plastics:

1. Adhesive Producers' Viewpoint: Bob Zins, Rubber & Asbestos Corp., Chicago, Illinois
2. Adhesive Users' Problems: Clayton Stevens, Kawneer Corp., Niles, Michigan

Problems in Adhesive Bonding: Production Planning, Production Control and Quality Control: Charles Latimer, Dir. of Res. and Development, Nickey Brothers, Inc., Memphis, Tennessee

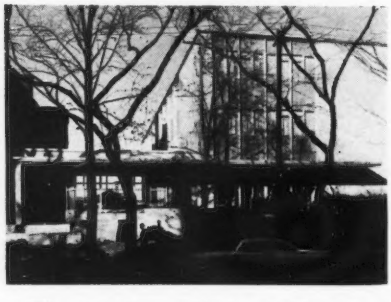
P. M.

1:00—The Future For Future Adhesives: G. W. Crain, Adhesives, Coatings & Sealers Div., Minnesota Mining & Manufacturing Co., St. Paul, Minnesota

New Glued Wood Products: Bruce Heebink, Eng. U. S. Forest Products Lab., Madison, Wisconsin

Trouble Shooting Adhesive Bonds

Presentation of Certificates



The meeting will be held in the new Wisconsin Center building on the main campus of the University of Wisconsin. This beautiful new building was created specifically for adult education programs and is admirably suited for an institute of this nature.

Further information may be obtained by writing Richard A. McCormick, 4016 Stadium, The University of Wisconsin, Madison 6, Wisconsin.

Conference Planned on "Profitable Use of Mill Residues"

Plans are being completed for the annual conference of the Utilization Div. of the N. E. Loggers Assoc., according to Fred C. Simmons, Chairman. The conference will be held at Glens Falls, N. Y., some time during the first two weeks of November. Papers will be presented on markets and specifications of the various salable products that can be made from slabs, edgings, veneer cores, and from fine material such as sawdust, shavings and bark. Among products to be discussed are: pulp chips; charcoal; particle board; mulch; soil amendment, and animal bedding. Meeting open to all interested persons.

Observation Team to Russia

A group of U. S. forestry specialists left uly 17 for the Soviet Union to observe research and management activities. They will visit laboratories, forestry schools and field operations. The team consists of: Dr. G. J. Jemisc , U. S. Forest Service; Dr. G. A. Garratt, Yale School of Forestry; Dr. R. Seidl, Simpson Timber Co.; Dr. A. J. Panshin, Michigan State U.; Dr. S. Pauley, U. of Minnesota; E. P. Stamm, consultant; Crown–Zellerbach; and Dr. L. J. Metz, U. S. Forest Service.

—NLMA Lumber Letter

Northeastern Beech Council Elects Officers

The Northeastern Beech Council, dedicated to the wider use of native Beech, has elected the following officers.

Gen. Chmn., Frank A. Reed, the Northeastern Logger, Old Forge, N. Y.; Research Chmn., Fred C. Simmons, N. E. Forest Exp. Station; and Publicity Chmn., Nelson Nash, Great Eastern Lumber Co., Glen Falls, N. Y.

Mr. Simmons stated that, "Until now there has been no central agency from which people could obtain correct information. The Council has made available a large library of practical publications, aimed for use by foremen and superintendents. These booklets cover the entire field, from logging to seasoning, machining and finishing of Beech. They are available without charge by writing the Council c/o Old Forge, N. Y.

Inroads of Competition

Aluminum is winning wider use as a home building material. Builders are planning to construct some 15,0 aluminum homes this year, an increa from several hundred in 1958. Mo standard houses will be equipped wi window frames, door knobs and oth parts made of aluminum. One produc predicts housing will take 50% mo aluminum in 1959 than last year.

—NLMA Lumber Letter

NAMES in the NEWS

DR. HALL

DR. LOCKE

Dr. E. G. Locke Named Director of U. S. Forest Products Lab

Madison, Wis.—Dr. J. A. Hall will retire Aug. 31 as director of the U. S. Forest Products Laboratory, and will be succeeded by Dr. Edward G. Locke, chief of the division of wood chemistry for the past 8 years, and former national president of FPRS.

Dr. Hall will take up residence in Portland, Oregon, where he will do consulting work. Hall retires as only the fifth director in the nearly half century the Lab has been in existence. He began his Forest Service career in 1930 as a biochemist on the Lab staff. In succeeding years he was served variously as assistant director and director of the California, Central States and Pacific Northwest Forest Experiment Stations, and on special assignment in Washington, D. C.

Dr. Locke, a native of Portland, Oreg., graduated in chemical engineering from Oregon State in 1928, and received his Ph.D. from Ohio State in 1932. In 1936 he became assistant professor of chemical engineering at Oregon State. He joined the Forest Service in 1944, working on development of a wood hydrolysis process; and upon Dr. Hall's appointment to the Madison post, he came to Laboratory to supervise an expanded program of research on production of industrial chemicals from wood.

DR. STAMM

G. G. GARLICK

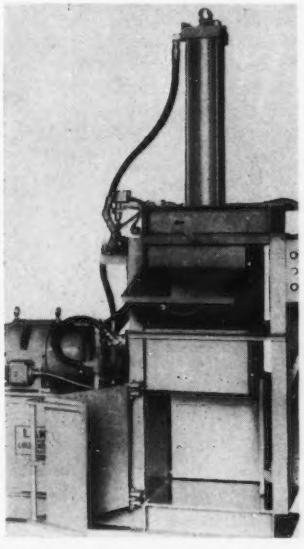
Dr. Alfred J. Stamm retired from the U. S. Forest Products Laboratory in midsummer after a brilliant 34-year career in research on the physical chemistry of wood. Not that "Dr. Stability" as he is affectionately known to his colleagues intends to hold still. This Fall he will join the faculty of North Carolina State College, Raleigh, to teach courses in wood chemistry. Dr. Stamm, author, holder of numerous patents, world-renowned in his field, has guided development of such familiar wood products as "impreg," "compreg," and "acetylated wood."

Gardner G. Garlick, v.p. and technical director of Protection Products Co., Kalamazoo, has retired after 38 years of service to his company and to the wood industry. One of the leading authorities in the U. S. on water repellents and preservatives, Mr. Garlick pioneered in water repellent preservatives for wood, as widely used today by millwork, lumber and allied industries. In his retirement, he will continue work on special projects as a consultant to the Company.

Dr. Eldon A. Behr, formerly v.p. in charge of research in wood preservation and technology for the Chapman Chemical company, Memphis, Tenn., has joined Michigan State University as associated professor in forest products. He will teach courses in wood preservation, wood technology and related areas. Dr. Behr earned his Ph.D. from U. of Minnesota in 1948.

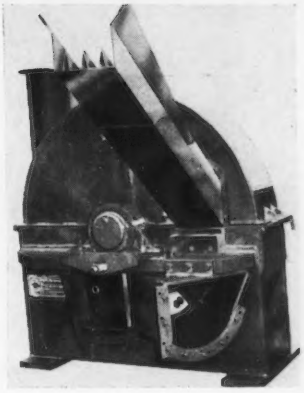
Leif D. Espenas, chief of physical research, Oregon Forest Research Center, has been named acting director of the Laboratory, succeeding **John B. Grantham,** who resigned to become chief of forest utilization research at the Pacific Northwest Forest and Range Exp. Station at Portland.

NEW PRODUCTS and Literature



Bulk Material Packaging Machine

An automatic Carton Packer has been developed to compact loose bulk materials such as sawdust, wood shavings, chips, pulp, and other materials, into corrugated cartons. Since these materials cannot be baled, and ordinarily require some sort of wrapping procedure, the Carton Packer is expected to reduce manpower requirements and speed up packaging. The packer is all steel, of welded construction, and powered by a 10 hp. electric motor. Inquiries should go to Lake Engineering Co., 312 Gostlin St., P. P. Box 784, Hammond, Ind.



Improved Horizontal Chipper

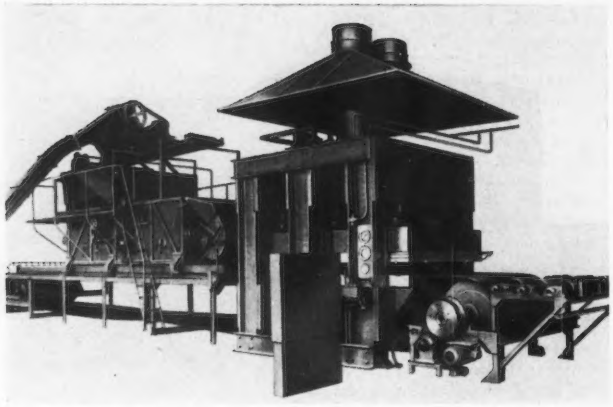
A nine-inch re-chipper infeed spout to handle oversize chips from the screen, cut-offs, and similar scrap, has been added to the design of the Soderhamn 48 and 56 inch horizontal chippers. The new infeed spout has three large channels bottomed to feed oversize chips correctly to the knife. This re-chipper can be added to similar existing chippers of any make. Direct inquiries to Soderhamn Machine Mfg. Co., Talladega, Ala.

Natural Finish for Wood Furniture

Fast, simple production for wood finishes of the flat, open grain, linseed oil and "Danish" types is said to be obtained by a new wood furniture Natural Finish. Production technique consists of saturation and drying. Finish is permanent, and multi-coat sealing, priming, or flat lacquer finishes have been eliminated, according to the manufacturer, Watco-Dennis Corp., 1640-20th St., Santa Monica, Calif.

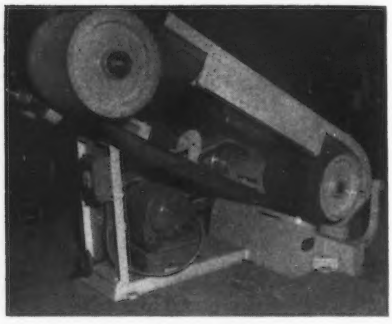
Permabond Wood Adhesive

Bonds of superior strength, capable of resisting heat and solvent action, are said to be attained by Permabond 665, a fast setting adhesive with good gap filling ability. Permabond requires no heating or processing and can be used at relatively low temperatures. Especially recommended for bonding maple and birch, this new adhesive is suggested for frames, dimensional stock, edge gluing, drawers, chairs, dowels, and plastic laminates. Manufacturer is the Continental Chemical Corp., 4 Smith St., Wakefield, Mass.



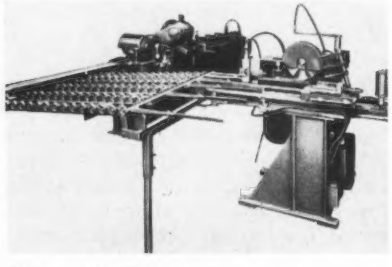
New Flakeboard Machine Announced by Soderhamn

Developed originally by one of Germany's largest producers of furniture, the Bison Board system offers many features. An air-separator chip spreader in an exclusive automatic mat-forming station concentrates larger chips to the center of the board, fines to the exterior, thus giving a graduated three-layer effect. The result is reported to be an exceptionally smooth finishing surface which will not "telegraph" through thin veneers. Installations as small as 17,000 sq. ft. per 24 hours. Write Soderhamn Machine Co., Talladega, Alabama.



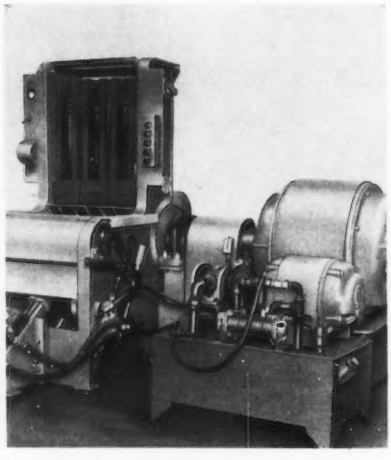
Improved Contact Sander

A new design in contact sanders uses a serrated rubber contact wheel to back up the coated abrasive belt for obtaining smooth finishes on all off-hand polishing work. Variable speed controls, rapid belt change, adjustable suction hood, and 6 to 14 inch serrated or soft wheels for contour work are additional features leading to high flexibility in operation. A positive, adjustable belt tracking device insures good belt life. The machine, designed to do 90 percent of the work ordinarily done on an open drum or pump drum sander, was developed by Murdock Machines, Statesville, N. C.



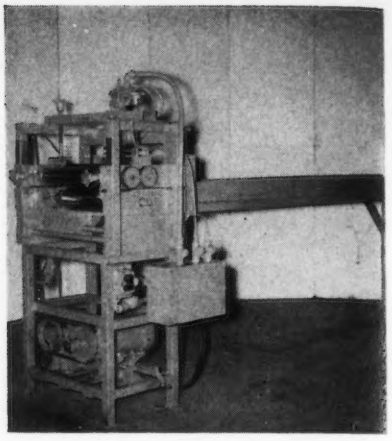
Finger Joint Shaper

The Onsrud Finger Joint Shaper and Assembly Machine. Reduces wood materials costs up to 25% or more by reclaiming shorts for production use and upgrading stock. Said to give up to five times greater production than by hand shaper. Write, Onsrud Machine Works, Niles 48, Illinois.



Flaking Machine

The 1826 flaking machine produces wood flakes of 1 in. length or to customer's requirements. Has cutterhead 18 in. in diameter and 26 in. long with 18 high-speed steel knives which are radially spaced and knotched. Handles logs 24 in. long and up to 10 in. in diameter. Uses 100 h.p. direct drive motor at speed of 1,800 r.p.m. Reciprocating feed bar operates at maximum of 12 strokes per minute. Thickness of flakes is varied by rate of speed. Has refuse removal and knife grinding attachment. Can be arranged for automatic feed and remote control. Write, Newman Machine Co., Inc., Greensboro, N. C.



Automatic Roller Coater

A roller coater designed for partial coating of stock combines electric eye limie switch control and variable timer to apply the coating in exactly the spot desired. This automatic "Pop-Up Top Coater" is furnished with roller lengths from 12 to 108 inches. A variable timer passes the sheets through the coater to a predetermined position where the coating roll lowers and applies adhesive. A second variable timer lifts the coating roll when the desired amount of adhesive has been applied. Introduced by the Union Tool Corporation, Warsaw, Ind.

What's New in *Technical Publications*

ASTM Standards on Wood, Wood-Base Materials and Preservatives

This 456-page compilation supersedes the 1954 editions, contains 69 standards. Includes methods for establishing structural grades for wood and timbers, evaluating properties, chemical analysis, fire tests, glued joints, etc. Covers wood, veneer, plywood, composition boards, etc. Obtainable from ASTM, 1916 Race St., Philadelphia 3, Pa. Price, $5.50.

The following publications are obtainable free of charge by writing, Forest Products Laboratories of Canada, Dept. of No. Affairs and National Resources, Ottawa, Canada:

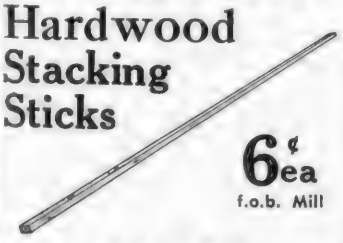
Deterioration of Logging Residue on the B. C. Coast, by J. W. Roff and H. W. Eades. Tech. Note No. 11, 38 pages.
Pulp Chips from Small Sawmills, by J. A. Doyle and G. W. Andrews. Reprint.
Efficiency of Scarf Joints, by A. P. Jessome. Tech. Note 9, 18 pages.
Short-Log Bolter, by W. W. Calvert. Tech. Note 10. 38 pages.
Lumber—Is its Future Secure? by J. H. Jenkins. Reprint.
How to Select Adhesives, by E. G. Bergin. Reprint.
Pulp Chips from Sawmill Residue in Canada. Reprint.
Spiral Grain in Wood, by P. L. Northcott. Reprint.
Physical and Anatomical Characteristics of Hardwoods, by J. D. Hale. Reprint.

The following publications are obtainable free of charge from the U. S. Forest Products Laboratory, Madison 5, Wis.:

eference Works on Pulp and Paper. ev. May 1959. No. 564.
urface Flammability of Wood-Base ilding Materials, by H. D. Bruce and E. Downs. May, 1959. No. 2140.
st of Publications on Seasoning of Wood. May, 1959. No. 446.
ortable Equipment for Measuring Twist Doors, by B. G. Heebink. May, 1959. o. 2148.
uing of Treated Wood, by M. L. Selbo. v. April, 1959. No. 1789.
ulping and Papermaking Experiments on signis Pine. Nov. 1958. No. 2124.
valuation of Wood Decay in Experiental Work, by Carl Hartley. Oct. 1958. o. 2119.
rimavera, by B. F. Kukachka. Rev. Dec. 958, No. 2021.
Properties of California and of Oregon White Oak, by B. H. Paul, A. W. Dohr, nd J. T. Drow. Oct. 1958. No. 2135.
Nailed and Lock-Corner Wood Boxes, Dec. 1958. No. 2129.
Factors that Influence Decay of Untreated Wood In Service and Resistance of Different Species. Rev. Oct. 1958. No. 68.
Groundwood Pulping of Balsam Fir and Jack Pine. Dec. 1958. No. 2139.
Water-Vapor Permeability of Matched Barrier Materials as Yielded by Two Methods. Sept. 1958. No. 2131.
Estimating Tree Specific Gravity from a Single Increment Core, by H. E. Wahlgren, and D. L. Fassnacht. April, 1959. No. 2146.
List of Publications on Chemistry of Wood. Mar. 1959. No. 238.
List of Publications on Fungus Defects in Forest Products and Decay in Trees. April, 1959. No. 508.
List of Publications on Boe and Crate Construction and Packaging Data. April, 1959. No. 791.
List of Publications on Growth, Structure and Identification of Wood. April, 1959. No. 177.
Using a Resistance-Type Wood Moisture Meter to Appraise Decay Hazard. April, 1959. No. 2147.
Comparison of Wood Preservatives in Stake Tests, by J. O. Blew. Mar. 1959, No. 1761.
List of Publications on Logging, Milling, and Utilization of Timber Products. April, 1959. No. 790.
Redwood Veneer Cutting and Drying Properties. Report 1766–8.
Pacific Madrone Veneer Cutting and Drying Prop. Report 1766–14.

(Advertisement)

One Car 6-foot Hardwood Stacking Sticks



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Virginia's Timber, by R. W. Larson and M. B. Bryan. 72-pages.
Survey of Wood Residue in Georgia, by R. H. Page and J. R. Saucier. Excellent economic analysis.
Grading and Measuring Hickory Trees, Logs and Products, by A. M. Herrick. No. 7 in a utilization series.
Southern Pulpwood Production, 1958, by J. F. Christopher and M. E. Nelson. Excellent economic review.

The following are available from the Dept. Forestry, U. of Illinois, Ag. Exp. Sta., Urbana, Illinois:

Farm Construction as a Market for Native Timber in Illinois, by J. K. Guiher and C. S. Walters.
Preservative Treatment of Fence Posts with Toxic Solutions. Note No. 82.
Preservative Treatment of Fence Posts by Cold-Soaking in Pentachlorophenol-Fuel Oil Solutions. Note No. 83.

Publications from Other Sources:

"Taxation and Conservation of Privately Owned Timber," proceedings of a conference held at the U. of Oregon, Jan. 1959. 100 pages. $2.00. Write, Bureau of Bus. Research, U. of Oregon, Eugene, Ore.

Wood Particle Board Manufacturing Opportunity in Georgia, by T. I. Chiang and B. W. Carmichael. A prospectus for interested firms. Write, Georgia Dept. of Commerce, Atlanta, Ga.

Floor Tile from Planer Shavings, by C. H. Burrows. Can be made by standard techniques for manufacturing particle board. Costs compare favorably with most commercial flooring materials. Inf. Circ. 12. Available, Forest Products Research Center, Corvallis, O.

Grading Southwestern Ponderosa Pine Logs, Research Note No. 10, College of Forestry, Colo. State U., Ft. Collins, Colo.
Wood Screws for Building and Wood Products, by E. G. Stern, Virginia Poly. Inst., Wood Research Lab., Blacksburg, Va. No. 39.

What's Known about Managing Eastern White Pine. All available information on the subject, concluding that control of white-pine weevil, and prevention of degrade through pruning are necessary for survival of this historic species. Available, N. E. Forest Exp., Sta., Upper Darby, Pa. 65 pages.

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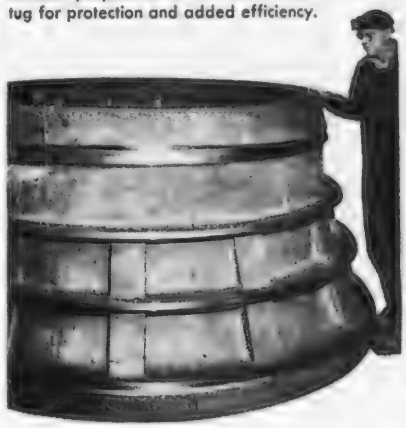

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EMPLOYMENT Opportunities

Inquiries concerning employment listings or ads to be placed in the JOURNAL should be addressed to FPRS Employment Service, P. O. Box 2010, University Station, Madison 5, Wis. Correspondence is kept confidential.

Employment Wanted

561—Assistant to research director. Available September due to laboratory closing. Experienced, training (MF) totals 17 years including R & D, admin., sales. Objective top management. Age 39, will relocate, resume on request.

562—Graduate of N.Y. State College of Forestry with BS in wood products engineering field available for employment July, 1959. Majored in wood utilization with courses in production management, finishing and personnel relations. Experience in wood products industries.

563—Single, 30 yrs. old. Desires job as wood research or for. ind. economics research or planning or administration, also education. A.B. degree from Cornell Univ. in Economics and M.F. from Yale in Management with heavy mixture of wood tech. & Fur. Prod. courses. Exp.

564—Public relation liaison contact man. Sales. Married, 48 yrs. old. Education and past experience are in the field of sound and production in radio and T. V. field.

566—Mich. State Univ., Wood Technology graduate, with a masters degree, desires a position in product development or as technical representative. Have had one year of experience in a plywood research laboratory.

567—Will receive B.S. in Wood Technology in August 1959 from Univ. of Mich. 27 yrs. old, married and two children. Veteran. Desires employment in production or sales, involving primary or secondary mfg. Available Oct. 1959 and prefers Northeastern states.

568—Executive, age 40, desires position as director of structural laboratory. Successful experience developing, planning and supervising research work in the general field of structural laminates. Presently doing research and development with large plywood corporation.

570—Age 27. Will receive Bachelor's Degree in Wood Products Merchandising from N. C. State College on 8/27/59. Desires Southern location. Prefers sales work. (Sept.)

571—Desires job in furniture production, teaching or research. Age 36. Married. Veteran. B.S. in Wood Utilization, M.S. in forest products. Also holds diploma for 9-mo. course in drafting. Experienced. (Sept.)

573—Position desired in marketing or management in the particle board industry with 8 yrs. of experience in quality control, product research and production in the particle board, hardboard and lumber industries. Holds B.S. degree in Wood Products with 5½ yrs. College. (Sept.)

Positions Offered

E 356—New position being created by multi-plant pressure treating company. Responsible for directing and improving treating techniques, maintaining quality of products and for liaison with all sources of technical information. Qualifications include a degree in wood technology or chemistry and at least ten years experience in the treating industry. Salary commensurate with these qualifications.

E 357—Full-time research position to develop a research program in wood technology and products at Midwest forestry school. Ph.D. required. Properly qualified person to be appointed at professor grade.

E 359—Semi-Technical Salesman to work in Northern California–Southern Oregon area calling on saw mills and other industries with national line of chemicals. Should have some sales experience and forestry or chemical background. Age 25 to 40. Salary plus incentive compensation. Please send resume and references. (Sept.)

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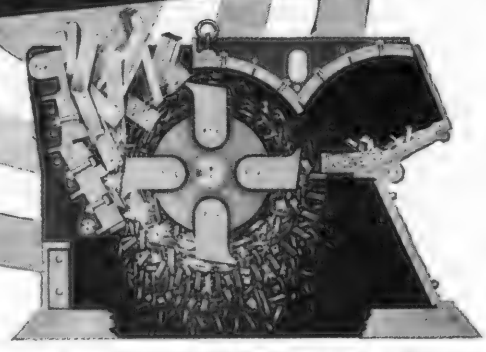

Cross section of "No-Nife" Hog showing how fast-revolving chisel-edge hammers reduce wood by impact until properly sized to pass through grate at bottom of machine.

1 Waste wood, automatically conveyed and hogged on Williams equipment, reduces disposal costs up to 75%! One man can handle as much tonnage in chips as three men can handle in awkward pieces and lengths.

2 **If used for fuel,** scrap wood hogged on a Williams is completely combustible, yields maximum BTU's, gives 100% heating value. Unhogged scrap restricts air flow, burns unevenly, smothers the fire, causes excessive smoke.

If sold in chip form to chip board manufacturers, wood refuse processed in a "No-Nife" Hog becomes a top quality product, uniformly ground and sized, and commanding highest prices.

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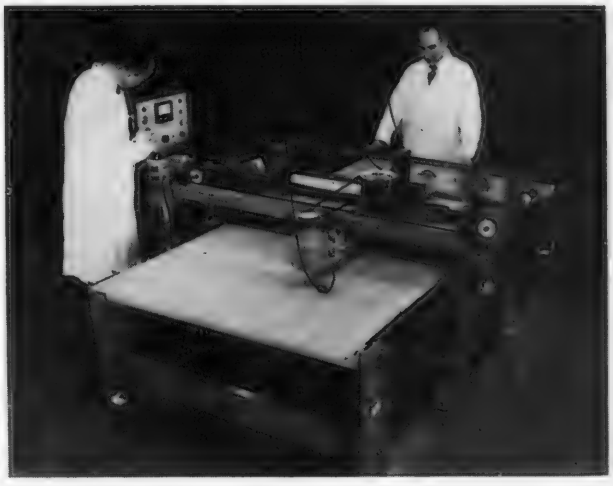
FPRS FOREST PRODUCTS JOURNAL
VOL. IX, NO. 8
AUGUST, 1959

FOR PLYWOOD AND OTHER BONDED MATERIALS:

Sonic Detection of Blisters[1]

D. G. MILLER
Forest Products Laboratory
Ottawa, Canada



Sonic blister detector

This investigation indicates that hidden blisters and defective glue bonds in bonded materials can be detected by changes in audio frequency vibrations at the location of the flaw. At feed rates of 100 feet or more per minute, satisfactory results were obtained even in the midst of competing mill noises.

IN THE MANUFACTURE OF PLYWOOD and other multilayer sheet materials, some panels may contain areas where there is no bond between two or more plies. Ths type of defect is often called a blister because in the production of hot-pressed plywood the defective bond is usually caused by the formation of steam from an area of higher moisture content in one of the plies. Other causes of blisters in plywood are variations in veneer thickness, non-uniform glue spread, and resin pockets.

Some blisters are visible as bulges or swellings when the panels first come out of the press and such panels are marked for rejection. In other cases, panels may contain flat blisters which have no measurable separation between the plies and hence give no visible indication of their presence. These are called hidden blisters and panels containing them can pass through subsequent operations, including grading and inspection, without detection of these blisters.

When a plywood panel containing a hidden blister is placed in service, changes in moisture content in the plywood may cause the plies to separate where the glue bond is defective and an objectionable swelling may appear on the surface of the plywood. If a panel is sawn through a hidden blister the plies may separate in the area of the blister. This separation detracts from the appearance of the plywood and may also affect its serviceability.

Much has been accomplished in improving production techniques to reduce the formation of blisters in plywood. Efforts in this direction have been handicapped by lack of a means for accurately assessing the effectiveness of corrective measures. On the other hand, it is recognized that complete elimination of a manufacturing defect, such as blisters, may not be feasible from a production viewpoint. The occurrence of blisters in a very small fraction of a plant's total production may not be serious, provided that such panels do not reach the market.

There is, therefore, an urgent need for an automatic device to rapidly inspect plywood production and to mark any panels containing hidden blisters. Thus, it could be ensured that such panels did not reach the market. Equally important, such a method of detection would be of great value in helping eliminate hidden blisters by indicating the effectiveness of corrective measures—taken to prevent their formation.

The Ottawa Laboratory of the Forest Products Laboratories of Canada began work on the detection of hidden blisters about two years ago as part of its research program on nondestructive methods of testing wood and wood products. Several different approaches to the problem were considered. Initially it was thought that hidden blisters might be detected by transmissions of ultrasonic vibrations through the plywood. However, because of the difficult problem of coupling transducers to rapidly moving sheets of plywood, ultrasonics did not appear suitable for automatic blister detection.

The approach that seemed the most promising is based on the fact that when the surface of a plywood panel containing a blister is rubbed or brushed, the sound produced as the brush moves over a blister area is slightly different to the ear from the sound produced over an area of normal glue bonds.

To investigate this approach, it was first necessary to obtain frequency spectograms of the sounds produced when samples of normal and blister plywood were stimulated into vibration. This work required the use of electro-acoustical instruments which were made available through the cooperation of the Acoustics Section of the Division of Applied Physics of the National Research Council, Ottawa.

Test Material

Most of the work on the detection of hidden blisters was done on Douglas fir plywood panels—of various

[1] A contribution from the Ottawa Laboratory of the Forest Products Laboratories of Canada, Forestry Branch, Department of Northern Affairs and National Resources, received May 13, 1959. Originally presented at FPRS, Pacific Northwest Section Meeting, Coos Bay, Ore., Feb. 2, 3, 1959.

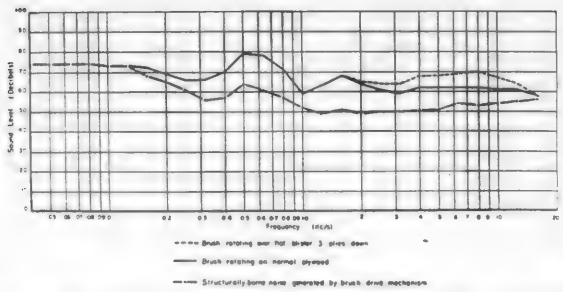


Fig. 1.—Spectrogram of brush sound from ¾-inch sanded Douglas fir plywood.

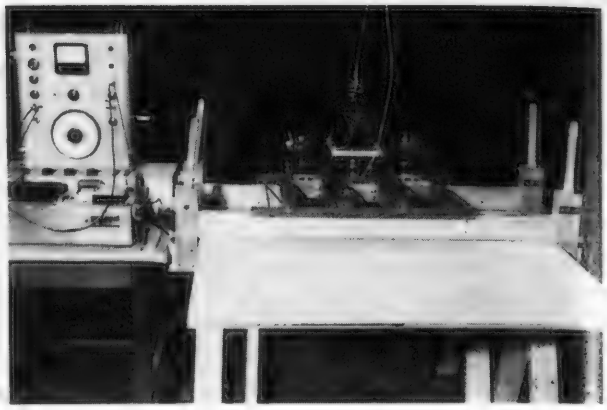


Fig. 2.—Apparatus for investigating the effect of adjacent brushes.

thicknesses from ¼ to ¾ inch—which contained simulated blisters. These panels were supplied by industry under arrangements made by the Vancouver Laboratory, FPLC. As might be expected, the most difficult blisters to detect in these panels were those between the innermost plies of ¾-inch plywood and, therefore, most of the work was done on this type of blister. In order to test plywood in which the blisters were perfectly flat, additional ¾-inch Douglas fir panels were prepared at the Ottawa Laboratory by gluing together three ¼-inch panels. Glue was not applied in the areas where blisters were desired.

Experiments With Rotating Brushes

A small paint brush,, with its bristles cut short, was used in the first experiments. A brass weight was attached to the top of the brush and this unit was free to move along a vertical shaft while being rotated by a small electric motor. Thus the brush and its weight were supported by the plywood and the pressure of the bristles on the plywood remained essentially constant in spite of any undulations in the surface of the plywood. A microphone was mounted near the brush, and spectrograms of the sound produced by normal and blister plywood were made by passing the output from the microphone through a Bruel and Kjaer (B & K) spectrometer Type 2109 to a B & K level recorder Type 2304 with a 50 decibels (db) logarithmic potentiometer. These spectograms show the level of each frequency in the brush sound.

Although the ear could detect a noticeable difference in the sound produced from the two types of plywood, this difference was difficult to detect in the spectograms. The reproducibility of the spectrograms from both types of plywood was poor, and erratic variability in the spectrograms obscured any fundamental difference between them. This variability appeared to be caused by extraneous noise and by vibrations in the motor and brush mounting.

Efforts were concentrated on eliminating these interferences. Quieter motors were tried, different types of brushes were tested, and various minor modifications were made in the apparatus. To improve the method of generating and picking up the brush sound, the microphone was mounted in the centre of a ring type brush (such as used in domestic floor polishers) and the brush was rotated by means of three loose fitting pins projecting down from a driven wheel above the brush. The brush was free to move vertically along the pins and hence the pressure of the bristles on the plywood remained constant.

Following these changes there was a noticeable improvement in the reproducibility of the spectrograms and a slight difference in the sound spectra of the two types of plywood started to become apparent. Between 2,000 and 16,000 cycles per second (c/s) the level in the spectrogram of blister plywood was consistently higher than in the case of normal plywood. The difference in levels appeared to be at a maximum at about 8,000 c/s. This meant that a *positive* indication of the blister could be obtained from an increase in the level of the 8,000 c/s component of the brush sound (Fig. 1).

With this apparatus a blister between the innermost plies of ¾-inch sanded Douglas fir plywood could be detected by an increase of at least 6db[2] in the 8,000 c/s signal. However, these tests were made in a quiet laboratory and the feasibility of using this sonic method of blister detection under industrial conditions hinged on the effect of plant noise on the sensitivity of the detector. Like many industrial plants, plywood mills are usually noisy. On the other hand, the level of sound generated by the brush is not very high and only the 8,000 c/s component of the brush sound is used by the detector.

[2] 6 db corresponds to a voltage ratio of about 2 — i.e., 6 db = $20 \log \frac{2}{10}$

Effect of Plant Noise

To investigate the effect of plant noise, sound level measurements and tape recordings were made of the noise in a local hardwood plywood plant at a location where a blister detector might be installed. The recordings were then played back in the laboratory and amplified until the level of the 8,000 c/s component of the recorded plant noise was, so far as possible, the same as in the plant.

The results of these tests indicated that plant noise would reduce the sensitivity of the detector as was anticipated, but to a much less extent than had been expected. The following two factors probably explain this result. Although the level of noise in the plywood plant is high, most of the sound energy is in the low frequency end of the noise spectrum. At the higher frequencies, the level of the sound falls off, and at the pertinent frequency of 8,000 c/s it is relatively low, at least in the sound recorded. On the other hand, the level of the 8,000 c/s component of the brush sound reaching the microphone is higher than was expected.

These results could not be considered conclusive because the level of the 8,000 c/s component of the recorded sound may not be representative of other plywood plants, and a loudspeaker cannot accurately reproduce the noise conditions of an industrial plant. Nevertheless, the results were considered to be very encouraging.

Effect of Brush Conditions

The effect of the speed of rotation of the brush on the performance of the detector was investigated with the range of speeds obtainable from the apparatus and it was found that

he level of the brush sound increased bout 10 db when the speed of the ush was increased from 100 to 400 p.m. However, the difference in db the level of the 8,000 c/s compo- nt caused by a blister remained sentially constant. Therefore, there no apparent advantage of a higher eed so far as the relative signal ength is concerned, but if necessary is signal strength could be main- ned in noisier surroundings by in- easing the brush speed. A brush ced of about 170 r.p.m. was used r most tests.

Similarly, it was found that the vel of the brush sound increased bout 2 db when the pressure of the bristles on the plywood was increased from 0.2 to 0.4 p.s.i. but the relative signal strength remained constant. Thus higher bristle pressure might be used to increase the absolute level of brush sound also.

The type of bristle used in the brush did not appear to be a critical factor in the performance of the detector. The main requirements of the bristles are that they be durable yet reasonably soft. The fibre bristles of the domestic floor polisher brush seem to meet these requirements very satisfactorily.

Effect of Adjacent Brushes

In order to obtain a high rate of inspection, an industrial plywood blister detector would probably have a number of detector units mounted in a row across a 4-foot width and each would operate independently as the plywood moved through the machine. The question was—would they operate independently or would they interfere with each other and thus reduce their individual sensitivity. To investigate this point a new experimental setup was prepared which had three rotating brush assemblies mounted in a row with a microphone in the central assembly (Fig. 2). In tests made with this apparatus on ¾-inch Douglas fir plywood the brush sound from the two adjacent brushes did not seriously affect the sensitivity of the detector and the results indicated that it would be feasible to have a number of detectors operate in close proximity to each other.

Marking Device

When the detector passed over a blister there was an increase in the 8,000 c/s signal from the amplifier and this increase was indicated on a meter. For industrial automatic operation it was necessary to provide a marking device which would be actuated by the increase in the signal. For this purpose an electronic relay was constructed which rectifies the signal and applies it to the control grid of a thyratron. A relay in the anode circuit becomes energized when the signal reaches a preset level. This relay can be used to operate a marking device or other indicating systems. The microphone amplifier and the electronic relay are adjusted so that the relay operates only when the level of the 8,000 c/s signal increases about 4 db above the level for normal plywood.

The method of marking consists of a pencil lead mounted on the end of a thin rod which is mechanically linked to a solenoid. The rod is located beside the microphone inside the hollow shaft in order that the mark will be made right on the blister.

Improved Brush Assembly

An improved rotating brush assembly was later developed, the details of which are shown in Fig. 3. The ring

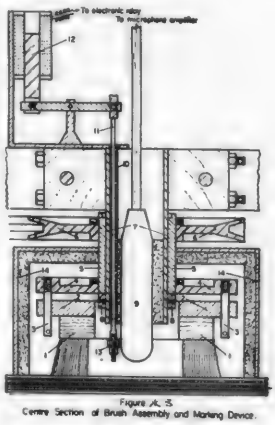


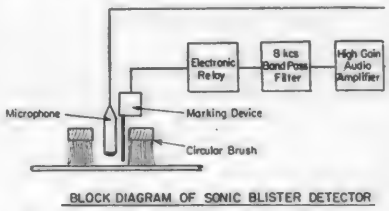
Fig. 3.—Centre section of brush assembly and marking device.

shaped brush (1) has a circular weight (2) fastened to its top. The brush and weight are rotated by metal pins (3) extending through the weight and fastened to a drive wheel (4) which is secured to a sleeve (5). The sleeve is fastened to a pulley (6) which is rotated by a belt to a small electric motor. The sleeve (5) rotates on a shaft (7) and is held up by the collar (8) fastened to the shaft. The shaft is securely clamped at its upper end to supports which hold the assembly above the plywood. The microphone (9) is mounted on soft rubber inside the shaft. A metal tube (10), also inside the shaft, supports a rod (11) which is mechanically linked at the upper end to a solenoid (12) and at the lower end to a marking pencil or pen (13).

The brush and its weight, which are free to move vertically along the length of the driving pins (3), are supported by the plywood being inspected. The metal cover (14), which is lined on the inside with sound absorbing material, encloses the brush but normally does not rotate. The cover is free to move vertically along the length of the sleeve (5) and is supported by the plywood being inspected.

Operation of Sonic Detector

The operation of the sonic blister detector is illustrated in Fig. 4. When the brush rotates on the plywood some



BLOCK DIAGRAM OF SONIC BLISTER DETECTOR

Fig. 4.—Block diagram of blister detector.

of the sound produced is received by the microphone and is converted into audio frequency electrical energy. This energy is amplified more than a billion times and is passed through a filter which allows only the 8,000 c/s band to pass through. The output from the filter is fed to the electronic relay which is adjusted so as not to operate when the brush is rubbing on plywood with normal glue bonds. A hidden blister between the brush and the central ply causes an increase in the level of the 8,000 c/s component of the brush sound. This increase causes the electronic relay to operate and a mark is made on the surface of the plywood over the hidden blister. The sensitivity of the detector drops off rapidly in the case of blisters below the central ply and is too low for satisfactory detection of such blisters. This means that the plywood must be inspected from both sides.

Laboratory Machine

After completing the experimental work, the next step was to build a machine capable of handling four by eight foot sheets to demonstrate the method and to carry out further experiments. Earlier in this paper it is indicated that an industrial machine would probably have a row of detector units operating independently and that the plywood would pass beneath them. Each detector unit would consist of a rotating brush assembly, a sensitive microphone, a high gain amplifier and filter, an electronic relay, and a marking device.

It was decided that the laboratory model should be limited to one detector unit which would scan back and forth as the plywood moved through. The rate of feed through the machine would, therefore, be limited by the rate of scan to about six feet per minute. This feed speed is, of course, too

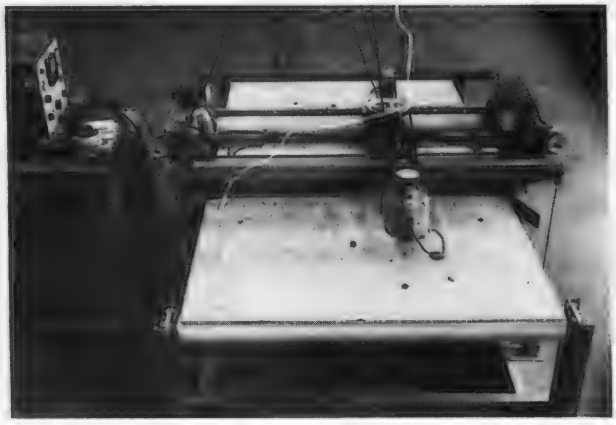


Fig. 5.—Laboratory model of plywood blister detector—with 4′ x 8′ panel—infeed end.

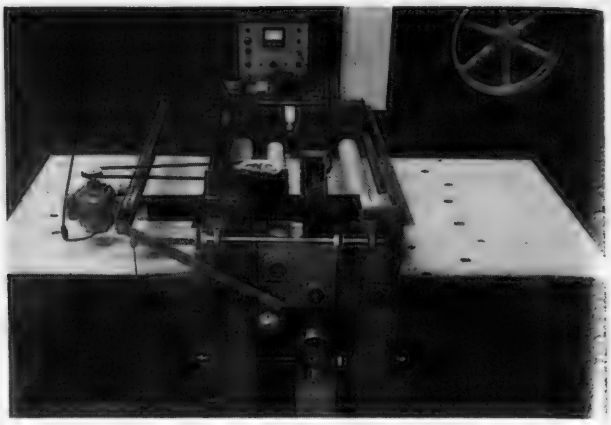


Fig. 6.—Side view of laboratory model of plywood blister detect

slow for industrial use but adequate for the purposes for which the pilot model was intended. The complete machine is shown in Figs. 5 and 6.

The scanning mechanism is driven by a small 3-phase motor which is capable of rapid and frequent reversing. Limit switches at the ends of the scan cause the motor to reverse. The machine is equipped with a device to lift the brush assembly when there is a large gap between successive panels passing through the machine. Such a gap might allow the brush assembly to drop down and the next panel would then jam against it. A photoelectric relay system switches off the marking circuit during the time that the gap between successive panels passes under the sound cover. This is to prevent ambient noise from reaching the microphone and causing a false indication. The microphone used in the detector of this machine is an Electro-Voice Model 647. The sound is amplified in a B & K microphone amplifier Type 2602 and the filter is the 8,000 c/s portion of the third octave filters in a B & K spectrometer Type 2109. The cover over the brush assembly is made of ⅛-inch sheet brass and is lined on the inside with a ¼-inch layer of sound absorbing felt. Two of the bottom rollers are power driven by a small motor through a speed reducing system.

Effect of Knotholes

Canadian Standards Association Specification 0121–1957 for Douglas fir plywood permits the inner plies of all grades except Marine to contain knotholes not larger in least dimension than one inch. Tests made with the laboratory machine on panels containing knotholes in the inner plies indicated that the detector would not respond to open knotholes below the second ply and would respond to those directly beneath the face ply only when the rate of movement of the detector over the plywood was slow in relation to the time constant of the electronic relay. In other words a one-inch knothole in the second ply gave a strong signal which would trigger the relay if the brush continued to rotate above the knothole. However, if the brush moved fairly quickly over the knothole, the signal produced, though strong, was of too short duration to trigger the relay.

Effect of Thickness and Surface Condition of Plywood

Both sanded and unsanded Douglas fir plywood panels of different thicknesses were run through the laboratory machine to determine the effect of the thickness and the surface condition of plywood on the performance of the machine. The level of the 8,000 c/s component of the sound produced when the brush was rotating on thinner plywood was higher than when the brush was rotating on ¾-inch plywood and, because the number of plies in thinner panels is less, a stronger indication of blisters was usually obtained when testing thinner panels. This change in the normal level of the 8,000 c/s component caused by a change in the thickness of the plywood can be compensated for by simply adjusting the gain of the audio frequency amplifier.

Tests made on unsanded plywood showed that the rough surface only slightly reduced the sensitivity of the detector. The roughness increased the variation in the level of the 8,000 c/s component from normal plywood but the added fluctuations were of very short duration and most were filtered out in the input circuit of the electronic relay.

High Speed Inspection of Plywood

An industrial plywood blister detector could be designed to mark the location and approximate size of each blister. Machines of this type wou be installed after each sander a would have a feed rate of about feet per minute.

An alternative arrangement wou be to use one high speed detector with a feed rate of about 100 feet p minute—after the trim saws. Such detector would merely mark pan which had blisters. These panels cou then be fed through a slow spe machine—comparable to the laborat model—which would mark the loca tion and size of each blister.

The rate of scan of the laboratory model is at least 100 feet per minute and the successful operation of this machine thus establishes the technical feasibility of blister detection at high rates of feed. Furthermore, after the laboratory machine had been tested, it was found that when the brush was scanning at 100 feet per minute, *but not rotating,* the relative motion of the bristles along the grain of unsanded ¾-inch Douglas fir plywood provided sufficient excitation to detect, under laboratory noise conditions, a six-inch blister between the innermost plies.

This result is very significant because at the trim saws, where the high rate of inspection is required, the panels are unsanded and it may, therefore, be possible to use non-rotating brushes in the high speed industrial model. Further tests are about to be made in a Douglas fir plywood plant to investigate the effect of the noise in the immediate vicinity of trim saws on the sensitivity of a detector with a stationary brush operating at a high rate of speed.

Since this paper was presented, t tests referred to here have been com pleted. The laboratory machine w installed and operated at a locati within a few feet of four high spe plywood trim saws, a slash saw f cutting up plywood trim, and a hopp for grinding plywood trim. The no level at this location is believed to

ver 100 db. In spite of the noise, hen the brush was scanning but not otating, 6-inch blisters 3 plies down n 3/4-inch fir plywood could readily e detected, and by increasing the ensitivity it was possible to detect a -inch blister 3 plies (i.e. 1/2-inch) own in a 7-ply 17/16-inch fir panel. n view of the fact that the effect of lant noise on the sensitivity of the achine could be reduced considerably y further soundproofing, it is consid-ed that the results of these tests es-blish conclusively that a high degree f sensitivity can be obtained in spite f industrial noise.

If the brushes on the high speed machine need not rotate, it then becomes a much simpler matter to design a brush system to operate on the under side of the plywood, and the machine could, therefore, inspect both sides of the plywood simultaneously.

Portable Blister Detector

The original project on blister detection was directed towards the development of an automatic device for rapidly inspecting flat plywood. Defective glue bonds can occur in other plywood products and other multilayer materials such as moulded plywood boat hulls, furniture panels, honeycomb constructions, laminated products, and various combinations of metals, plastics, and wood. For the inspection of these materials, a more versatile type of detector is required which need not be automatic, nor particularly rapid, but which should be able to operate in any position on both flat and moderately curved surfaces. It should be more in the nature of a portable hand tool.

To meet this requirement, the Ottawa Laboratory has developed the portable detector shown in Figure 7. Except in certain details, the construction is similar to the detector unit in the laboratory machine. In order to reduce the size of the brush the microphone is located outside it. Three pins, equally spaced around the brush, control its position relative to the surface under test so that the bristles press on the plywood with constant pressure. The speed of rotation of the brush is 1,500 r.p.m. The construction has been made as light as possible with a total weight of approximately ten pounds.

Summary

The investigations covered by this paper have shown that hidden blisters and defective glue bonds in plywood and other bonded materials can be detected by a device which responds to an increase in the level of the higher frequency components of the audio sound produced when a brush passes over the defective bond. Tests made with recordings of noise in a plywood plant indicated that, with suitable soundproofing, this method of flaw detection would function satisfactorily in spite of the noise encountered under industrial conditions. Further investigations made with apparatus having three rotating brushes indicated that a number of detectors can be operated in close proximity to each other without causing excessive interference. A laboratory machine with one detector which scans across the direction of feed through the machine has been built and operated successfully. Tests made with this machine in a Douglas fir plywood mill indicate that when the rate of feed of unsanded plywood is about 100 feet per minute, or greater, blisters can be detected with a high degree of sensitivity with stationary, i.e., non-rotating brushes in spite of a high level of mill noise. A portable blister detector has been developed for inspecting curved plywood and small panels of other multilayer materials.

Patents covering this method of flaw detection and the device involved have been applied for in Canada and the United States. A license to manufacture commercial blister detectors has been granted by Canadian Patents and Development Ltd. to Argus Engineering and Development Limited, 8638 Ash St., Vancouver 14, B. C.

Acknowledgement

The author wishes to thank Dr. G. J. Thiessen, Head of the Acoustic Section at the National Research Council, Ottawa, for making equipment and facilities available for this project, and to gratefully acknowledge the assistance and advice given by Dr. Thiessen and his colleagues.

Discussion

QUESTION: Can the machine be adjusted so that permissible defects in the inner plies such as knotholes will not be picked up and marked as blisters?

ANSWER: Yes, the sensitivity of the detector can be adjusted to overlook permissible knotholes.

QUESTION: Does the operation of the machine vary with species or resonant frequencies?

ANSWER: Resonant frequencies are not involved in this method of flaw detection and the species of wood in plywood does not affect the detector's operation.

QUESTION: How do you explain that?

ANSWER: A blister causes a local change in the acoustic impedance of the plywood which results in an increase in the amplitude of the higher frequencies in the sound generated by the brush. This phenomenon does not seem to be affected by the modulus of elasticity of the material being inspected, at least not over the range of elastic moduli normally encountered in wood. The response of the detector is due to the increase in the amplitude of the higher frequencies and not to any resonant frequencies.

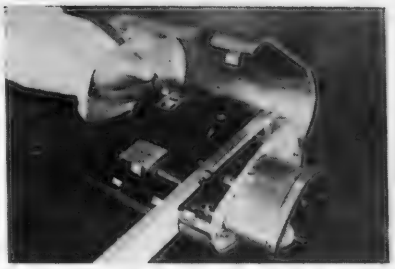


Fig. 7.—Portable plywood blister detector.

QUESTION: What is the estimated F.O.B. installed price of the detector?

ANSWER: Only a rough estimate can be given at this time, but it is expected that the cost of an industrial model, with a rate of feed of 100 linear feet per minute, would be under $15,000.

QUESTION: Will this machine require much servicing?

ANSWER: Since the mechanical construction of an industrial model would be quite simple, and electronic components are not complicated, very little servicing should be required.

QUESTION: What is the minimum size of blister that the detector will pick up?

ANSWER: The laboratory machine has detected blisters slightly under six inches in diameter, between the innermost plies of 7-ply 3/4-inch fir plywood. The portable model, because of its smaller brush, can detect somewhat smaller blisters.

QUESTION: Will the detector pick up a very low quality bond, but one that is not a delamination?

ANSWER: No, the detector will not respond to a weak but continuous bond.

QUESTION: Will this device detect the presence of rough core where the bond occurs only on the high spots?

ANSWER: The detection of this condition has not been investigated. However, if the spaces between the ridges are larger, the detector probably could pick up the spotty bond. Incidentally, tests did reveal that it will detect an area of ring shake in a face ply.

QUESTION: What type of bristles are used on the detector brush?

ANSWER: The bristles are the type used in brushes of a domestic floor polisher. As yet other bristle materials have not been investigated. In general the bristles should be durable, but sufficiently soft that the surface under test is not affected.

EFFECT OF LAMINATION THICKNESS ON

Strength of Curved Laminated Beams[1]

W. J. Finnorn and A. Rapavi

White oak beams of different lamination thicknesses (72 inch radius of curvature) were tested in bending. Over the range tested, lamination thickness did not affect beam strength.

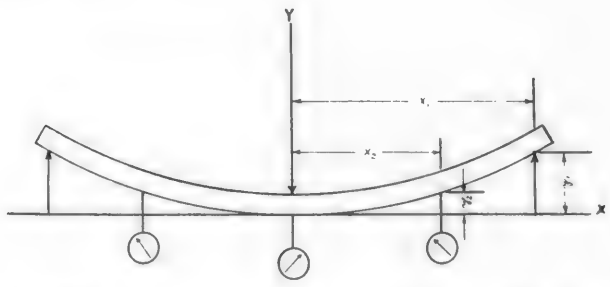


Fig. 1.—Diagram of the test setup, showing how deflection readings were used to esta lish points in a Cartesian coordinate system in the determination of the equation of the cu representing the convex face of a test specimen at proportional limit or rupture.

THE UNITED STATES NAVY has always relied heavily on wood as a ship and boat building material, but with the great demand for wood during World War II, it became evident that high-quality white oak traditionally used in shipbuilding was rapidly becoming scarce.

This shortage and the development of the laminated wood arch for indoor structural purposes prompted the Navy Department's Bureau of Ships to sponsor an extensive research program at various government and private laboratories to develop wood laminates as a substitute for solid shipbuilding materials. New adhesives and fabrication techniques provided wood laminated with fully waterproof adhesive bonds able to withstand severe exposure to salt water and extremes in wetting and drying.

Several thousand laminated keels for LCVP boats were put into service with much success. Experience and further research showed the laminate to be not merely a substitute for solid wood, but a new material that offered a number of advantages over solid, built-up structures.

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With this new material came the need for new design considerations. One of the pertinent problems involved in the production of wood laminates for use in U. S. Navy wood ships and boats was the large variety in sizes and shapes of the various structural components of a vessel. Some shapes required individual layers (laminations) of members to be bent to rather sharp radii of curvature. Therefore, the Bureau of Ships was faced with the problems of learning the extent to which a piece of lumber or a lamination can be bent without damage, and of determining the ultimate effect of the bent layer on the strength of the over-all laminate.

Based on work done in connection with radii of curvature considerations for commercial arches, the Forest Products Laboratory developed the following curvature factor for use in calculating working stresses for curved laminates (1):[2]

$F_C = 1 - [2000\ (t/R)^2]$ in which t is the thickness of lamination and R is the radius of curvature of laminations. The Laboratory reports this formula applicable to both hardwoods and softwoods, and in commercial application it is generally the accepted method for adjusting working stresses to take into account the effect of curvature and lamination thickness on strength. It was assumed, however, that a formula specifying maximum lamination thickness as a function of curvature and requiring no reduction in working stress would be less cumbersome for use in over-all design of shi and boat laminates. Also, the abo formula appeared to be conservativ and required impractically thin lami ates for some sharply bent members

Various formulas developed on t basis of theoretical considerations showed the radius of curvature to which a given wood could be bent as some constant times thickness. But these equations also required very thin laminations for relatively sharp curvatures. In light of these problems, tests were conducted in which boards of different thicknesses were bent to failure and the resulting curvatures were adjusted to give an approximate safe bending radius for each thickness. The radii of curvature-lamination thickness relationship in U. S. Military Specifications governing the production of wood laminates for Navy use were evolved in this manner. Although more practical than the theoretical formulas, there were indications in production that the permitted radii for some lamination thicknesses were too sharp. There was also evidence that some thicknesses of lumber could be safely bent to radii of curvature sharper than those specified.

Thus a need still existed for fu ther detailed study of curvature-thick ness relationships and their effects the ultimate strength of laminate members. The Bureau of Ships is no sponsoring such an investigation at t Timber Engineering Company's r search laboratory.

The project is being conducted two phases: 1) the determination proportional limit and rupture rad for individual boards; and 2) the fa rication and strength testing of lam

[1] The views expressed by the authors is not to be construed as representing those of the Department of the Navy.

[2] Numbers in parentheses refer to the Literature Cited at the end of this paper.

ated beams to study the effect of hickness—curvature relationships, on he basis of information obtained nder Phase 1. The importance of hase 1 was emphasized in early work, hich indicated that white oak and)ouglas-fir of equal thickness reach roportional limit at approximately the me radius but that, before failing, k bends to much sharper curvature an does Douglas-fir. These differ- ices must be taken into account in eparation of curved beams tested nder Phase 2.

Experimental Procedure

Testing of Individual Boards: In initial work on this project, proportional limit and rupture radii were determined for each board by bending it repeatedly, to successively smaller radii of curvature, until failure occurred (2). The amount of induced bow or set in the board 5 minutes after it was bent to each radius was measured. As radius decreased, set increased at a constant rate until a critical radius was reached at which a large increment of set occurred. This was assumed to be the "proportional limit radius".

This method was very time-consuming, and the proportional limit radius was not directly related to stress and strain. A new method was therefore devised in which a board is subjected to a single static bending test. It is simply supported over a span and center-loaded at a rate of 0.1 inch per minute. Three dial gauges calibrated in thousandths of an inch are used to measure deflection at mid-span and at intermediate poitns between "center-span" and the end supports, as shown in Fig. 1. Since it is necessary to determine deflection from a true plane rather than from the surface of the unstressed board, which could be slightly bowed or twisted, a straight reference line is determined by placing a flat steel plate across the span and taking zero dial gauge readings from this "plane".

As the board is bent, deflection is measured at the three points at uniform intervals of load until failure occurs. Load at proportional limit is then determined by plotting load over center-span deflection.

A procedure described by Brink (3) is then employed to determine the equation of the conic section through five points along the convex face of the board at proportional limit and also at rupture. The curve, or conic section, is considered to be in a Cartesian coordinate system (Fig. 1), with the "center span" of the board the origin or point (0, 0). The end supports are at points $(+ x_1, y_1)$ where x_1 equals ½ the span length, and y_1 equals the total deflection. The intermediate gauges are taken as points $(\pm x_2, y_2)$ where x_2 equals the spacing between gauges and y_2 equals the center deflection minus the intermediate gauge deflection.

To demonstrate the process used, assume that the deflection at proportional limit for a ¾-inch-thick white- oak board tested over a 24-inch span was .472 inch at the center gauge and 0.322 inch at gauges 6 inches to the left and right of the center.

When placed in a Cartesian coordinate system, as shown in Fig. 1, the center point is at 0, 0), the end supports are at $(\pm 12, 0.472)$ and the intermediate points are at $(\pm 6, 0.472 - 0.322)$ or $(\pm 6, 0.150)$.

The equations of the four straight lines that connect the points determined by the end supports and the intermediate gauges are:

$$y - 0.472 = 0$$
$$y - 0.150 = 0$$
$$6y + 0.322x + 1.032 = 0$$
$$6y - 0.322x + 1.032 = 0$$

The equation of the system of conics through the four points is:

$$(y - 0.472)\ (y - 0.150) + k\ (6y + 0.322x + 1.032)\ (6y - 0.322x + 1.032) = 0$$

The value of k, determined by substituting the coordinates of the fifth point (0, 0) for x and y in this equation, equals — 0.0665.

The equation of the conic through the five points is obtained by inserting this value of k into the above equation and simplifying to the following form:

$$x^2 = 202y^2 + 210y$$

The radius of curvature at the origin or center of the span is then determined by applying the following formula to the above equation:

$$R = \frac{[1 + (dy/dx)^2]^{3/2}}{\frac{d^2y}{dx^2}}$$

where

R = radius of curvature of the convex face of the board.

In the example given, the radius is found to be 105 inches.

Testing of Laminated Beams

Under the second phase of this study, 20 beams approximately 6 by 6 inches in cross section were fabricated and tested to determine the effect of lamination thickness and grain orientation (flat and vertical) on the strength of curved and straight laminated beams made up of clear, straight-grained white oak.

For each lamination thickness given in Table 1, one straight beam and one curved specimen laminated to a 72-inch radius of curvature were fabricated for each of the two grain orientations.

Table 1.—DEPTH OF BEAMS COMPOSED OF A GIVEN NUMBER OF LAMINATIONS OF THE THICKNESSES USED IN THIS STUDY

Lamination thickness Inch	Number of laminations	Beam thickness (including 0.003 inch per glue line) Inch
0.269	22	5.98
.401	15	6.06
.531	11	5.87
.663	9	5.99
.751	8	6.03

The 72-inch radius of curvature was used since tests of individual laminations indicated that 0.531-inch-thick white oak boards reach proportional limit at approximately this curvature (Table 2). Thus the two thinner laminations were not stressed to proportional limit, while the thicker ones substantially exceeded this point.

Lumber used in the beams was conditioned to approximately 12 percent moisture content. Laminations for each beam were selected by a system of random numbers from the lumber of the appropriate grain orientation. They were surfaced to the desired thickness with a tolerance of ± 0.005 inch not more than 8 hours before the beams were fabricated.

The specimens were glued with a resorcinol-phenol resin adhesive used according to manufacturer's instructions and cured for not less than 6 hours at a glue-line temperature of 150° F.

Testing Procedure: Strength testing was conducted in a Baldwin–Southwark Universal testing machine. All beams were center-loaded over a

Table 2.—RADII AT PROPORTIONAL LIMIT AND RUPTURE AS DETERMINED BY TWO TEST METHODS

Test method	Thickness Inch	Average specific gravity[1]	Average moisture content Percent	Av. proportional limit radius Inches	Average radius at rupture Inches
Repetitive loading	½	.72	11	40	10
	⅝	.74	11	59	16
	½	.70	11	72	21
	⅝	.73	10	89	32
	¾	.66	10	106	42
Center loading	¼	.69	11	35	8
	½	.69	12	66	18
	¾	.64	12	103	26

[1]Based on oven-dry weight and oven-dry volume.

Table 3.—RESULTS OF BENDING TESTS CONDUCTED ON STRAIGHT BEAMS AND ON BEAMS LAMINATED TO A 72-INCH RADIUS OF CURVATURE. (STRENGTH VALUES ARE ADJUSTED FOR SPECIFIC GRAVITY AND CURVATURE)

Type of beam	Grain orientation	Lamination thickness Inch	Average moisture content Percent	Effective specific gravity[1]	Fiber stress at prop. limit psi	Modulus of rupture psi	Modulus of elasticity 1000 psi	Work to proportional limit In. lb/cu. in.	Work to maximum load In. lb/cu. in.
Curved[2]	Flat	0.751	12.4	0.68	7305	15,724	1365	1.87	17.31
		.662	12.2	.69	8843	15,248	1284	2.90	13.09
		.531	12.6	.74	8212	16,751	1449	2.27	17.05
		.401	12.1	.73	8108	16,020	1523	2.34	12.39
		.269	12.4	.73	8347	15,906	1511	2.29	14.37
Straight	Flat	.751	12.0	.73	7867	16,046	1609	2.15	17.72
		.663	12.7	.78	7051	13,108	1337	2.20	14.56
		.531	12.4	.74	8135	14,575	1474	2.52	12.42
		.401	12.5	.71	8191	14,035	1692	2.19	10.69
		.269	12.6	.70	9311	15,488	1495	3.18	14.26
Curved[2]	Vertical	.751	11.9	.70	6848	12,133	1191	1.95	9.03
		.663	11.1	.70	6341	11,815	1200	1.66	7.95
		.531	11.8	.72	6350	11,792	1325	1.49	6.60
		.401	11.0	.72	6257	11,502	1278	1.56	7.44
		.269	11.9	.73	6224	10,411	1150	1.72	6.08
Straight	Vertical	.751	11.6	.75	6111	8,643	1185	1.78	4.04
		.663	11.6	.67	7146	10,874	1404	1.92	5.68
		.531	11.0	.71	5848	8,993	1135	1.67	4.94
		.401	10.8	.71	5870	10,089	1215	1.56	5.81
		.269	11.7	.73	5230	9,950	1210	1.26	6.01

[1]Specific gravity based on oven-dry weight and volume for each lamination and calculated according to the formula: $G_e = 1/I \quad i=1 \quad G_i I_i$ (For explanatio see text)

[2]Bent to a 72-inch inside radius.

66-inch span at a constant rate of speed of the loading head of 0.182 inch per minute. The center load was applied to the convex face of curved beams. The ends of the specimens were supported on knife edges on a system of plates and roller bearings in such a way that the span remained fixed and the end movement unrestrained. Deflection was measured by means of a dial gauge to the nearest 0.001 inch. Each specimen was tested to failure.

Immediately after test, a cross-sectional piece was cut from each beam. This was then re-sawed so as to provide a moisture content-specific gravity specimen for each lamination within the beam. When the moisture content and specific gravity (oven-dry weight and volume) were determined, they were recorded for each lamination in the order of its position in the beam.

Strength Calculations: Fiber stress at proportional limit modulus of rupture, modulus of elasticity, work to proportional limit, and work to maximum load were calculated for each beam.

Adjustment of Strength Values: Although the lumber used in the test beams was randomly selected, the relatively small number of specimens tested per variable made it necessary to adjust the strength values to a comparable basis.

Moisture Content: Moisture content was closely controlled, with most of the specimens (13) averaging 12 percent and the others within ±1 percent. Therefore no correction was made for this factor.

Specific Gravity: Specific gravity could not be closely controlled because of the relatively large quantity of lumber and considerable time that would have been involved. Instead, the boards used were selected, by a system of random numbers, from clear, straight-grained white oak lumber with approximately a normal specific gravity range with a 0.72 average.

Because of the specific gravity range that did occur, the strength values of each laminated beam were adjusted according to the following formula:[3]

$$S_a = S_u (.72/G_e)^n$$

where:

S_a = strength adjusted to a specific gravity of 0.72
S_u = unadjusted strength
G_e = effective specific gravity of the laminated beam
n = an exponent with a value of 1.50 for fiber stress at proportional limit and modulus of rupture; 1.25 for modulus of elasticity and work to proportional limit; and 2.00 for work to maximum load

The effective specific gravity G_e used in the foregoing equation was calculated for each beam according to the following formula:

$$G_e = \frac{1}{I} \sum_{i=1}^{i=n} G_i L_i$$

where:

G_e = effective specific gravity
G_i = specific gravity of the i th lamination
I = moment of inertia of the beam, inches[4]
I_i = moment of inertia of the i th lamination with respect to the neutral axis of the beam, inches[4]

[3] This formula is based on the equation $S/S' = (g/g')^n$ from Design of Wood Aircraft Structures, ANC Bulletin 18 (4).

This formula is a method of weighing the specific gravity of each lamination according to the distribution of stresses throughout the beam.

Curvature: In determining the fiber stress at proportional limit and modulus of rupture of curved members, results obtained by the standard equations were modified by multiplication by a factor K determined by the following formula (5):

$$K = 1 + 0.5\frac{I}{bc^2}\left[\frac{1}{R-C} + \frac{1}{R}\right]$$

where:

K = curvature factor
I = moment of inertia of the section, inches[4]
b = width of beam, inches
C = ½ beam depth, inches
R = radius of curvature to the centroid of the beam, inches

K does not compensate for the stresses built into curved beams; it merely allows for the fact that, because of shape, more stress develops in the concave face of a curved beam under a given bending moment, than would develop in either face of straight members under an equal moment.

Results and Discussion

Individual Laminations: Average radii at proportional limit and rupture for clear, straight-grained white oak boards as determined by repeatedly bending to successively smaller radii and by center-load static bending tests are shown in Table 2.

Laminated Beams: The strength values for each laminated beam adjusted for specific gravity and curvature are presented in Table 3.

An analysis of variance run on the data presented in Table 3 indicates that, for the range of thicknesses and the curvature tested, thickness had no significant effect on strength. This is in spite of the fact that many laminations thicker than ½ inch were probably stressed beyond proportional limit. Several feasible explanations for this have been broached, but, as yet, no experiments have been conducted to test the validity of the theories involved.

Modulus of rupture and work to maximum load values were higher for curved beams than for the straight members (at the 5 and 10 percent significance levels, respectively). No significant differences were found between curved and straight beams when fiber stress at proportional limit and work to proportional limit were compared.

The analysis also indicated that, in every calculated strength property, the beams made up of flat-sawn lumber were very significantly stronger (at the 0.1 percent level) than those composed of quarter-sawn or vertical-grain lumber. However, a series of tests conducted under another phase of this study on laminated beams composed of boards that had been selected from the same batches of lumber indicated that the quarter-sawn material used was inately weaker than the flat-sawn lumber, regardless of direction of loads with respect to the annual rings. This was further substantiated by a series of toughness tests conducted on samples selected from each batch.

Conclusions

1. The strength of straight, white oak laminates is not significantly affected by individual lamination thickness.

2. Lamination thicknesses ranging from ¼ to ¾ inch have no significant effect on the strength of white oak beams laminated to curvatures no sharper than 72 inches, when loads are applied in a general radial direction to the convex faces of the beams. No specimens were tested with loads applied to their concave faces, so no conclusions can be drawn regarding the effect of lamination thickness on the strength of beams loaded in this manner.

3. Although, in the work described in this article, beams composed of flat-sawn lumber proved to be significantly stronger than those made up of quarter-sawn lumber, it should not be concluded that this was due to grain orientation. Work done under another phase of this project indicated that the wood of the quarter-sawn lumber used was inherently weaker than that of the flat-sawn lumber.

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Assaying Penta-Treated Wood

BY MEANS OF DIAZO COMPOUNDS[1]

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A practical, inexpensive qualitative method that does not depend on the presence of the solvent is needed for determining the distribution of pentachlorophenol in treated products. This report reviews the methods that have been tested, and also describes a series of tests in which pentachlorophenol is coupled with a diazotized amine to form a colored compound.

PENTACHLOROPHENOL, A LIGHT-colored, oil-soluble compound that is highly toxic to wood-destroying fungi and insects, has found general acceptance for the preservative treatment of many kinds of wood products. The depth to which a preservative chemical penetrates the wood is a reliable indicator of service life. Since pentachlorophenol imparts little, if any, color to wood impregnated with it, the qualitative assay of the treatment at present is difficult or impractical.[2]

Chemical analyses have shown that color imparted by the oil solvent may be used to determine the depth of toxicant penetration. Many times, however, a light-colored solvent is used and the depth of penetration is indistinguishable.

Several qualitative methods of determining pentachlorophenol penetration in wood have been investigated at the Illinois Agricultural Experiment Station. Briefly, they included the use of transmitted light in which an increment core from freshly treated wood was placed in a narrow slot in a wooden box. A 150-watt light placed inside the box and beneath the core often showed the part of the core penetrated by the preservative solution to be translucent. The use of ultra-violet light (3750 Å) was not particularly successful. Increment cores from

[1] A contributed paper received October 1, 1958.

[2] A quantitative method has been adopted by the American Wood-Preservers Association (1), but laboratory facilities are required for the assay.

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treated posts were dipped in a 10-percent solution of sodium acetate, followed by a dip in a 0.1N solution of silver nitrate, and air-dried (10). The formation of yellow-colored silver pentachlorophenate indicated the depth of penetration. None of these techniques was wholly satisfactory.

The development of the "dye-bed" technique (14)[3] led to a series of methods which used oil-soluble dyes and fluorescent materials (3) to indicate the presence of pentachlorophenol. These methods have one major objectionable feature, however: they depend upon the presence of the solvent to indicate the distribution of the toxicant. Some of the methods may be messy, impractical for field use, or they may not define toxicant distribution with clarity and preciseness.

A modification of the Beilstein test (2) is highly useful for indicating the presence of pentachlorophenol in treated wood. The method is based upon the principle that if treated wood is burned in a copper container, the chlorine liberated reacts with the copper to form copper chloride. Copper chloride gives the flame a vivid green color. It is difficult to precisely measure the depth of toxicant penetration in fraction of an inch by the Beilstein test.

The Sandermann-Jonas technique (12) (chlorite test) gives a rather precise picture of the distribution of pentachlorophenol. Translations of the original article, or abstracts of it (4), and instructions for the test are available from the manufacturers of pentachlorophenol. The method is rather difficult to apply under field conditions, however, and it works best with small samples.

Sakornbut and Morrill (11) described a modification of the chlorite test in which they used a leuco base as a color-forming reagent. The test was reliable only when applied to freshly exposed wood surfaces, and an oxygen-free chamber was required to develop the colored compounds from pentachlorophenol. The authors also indicated that "The amount of pentacholorophenol, and consequently of chloranil, to react with the leuco base is very small in the vicinity of the detectable limit, probably in the order of a microgram per square millimeter. Volatilization of pentachlorophenol is likely to cause a significant reduction of the surface concentration upon prolonged exposure."

Thus a method is needed that will define the distribution of pentachlorophenol (not the solvent) clearly and precisely. The method must be practical for field use and reasonably simple to apply.

[3] Numbers in parentheses refer to the Literature Cited at the end of this paper.

Table 1.—ARYLAMINES, THEIR MOLECULAR WEIGHTS, AND THE METHOD OF DIAZOTIZATION USED TO PREPARE THEIR DIAZONIUM SALTS

Amine	Molecular weights	Diazotization process
p-amino-dimethylaniline	136	$NaNO_2$ solution added to a cold solution of amine in aqueous HCl
p-amino-diethylaniline	164	$NaNO_2$ solution added to a cold solution of amine in aqueous HCl
1-amino-2-naphthol-4-sulfonic acid	241	Paste prepared with H_2O and cooled; solution of $CuSO_4$ and $NaNO_2$ added to paste and the liquid filtered; HCl added to liquid
anthranilic acid	137	Dissolved in hot H_2O, HCl, and cold solution of $NaNO_2$ added in order listed
o-chloroaniline	128	"
p-chloroaniline	128	"
p-bromoaniline	172	"
p-iodoaniline	219	"
α-naphthylamine	143	"
β-naphthylamine	143	"
1-naphthylamine-4,8-disulfonic acid	303	"
2-naphthylamine-4,8-disulfonic acid	303	"
2-naphtholamine-6-sulfonic acid	223	"
m-nitroaniline	138	"
o-nitroaniline	138	"
p-nitroaniline	138	Dissolved in warm solution of HCl and H_2O; cooled $NaNO_2$ added
2-nitroaniline-o-sulfonic acid	218	
sulfanilic acid	173	Added to NaOH; then $NaNO_2$, and HCl added in order listed

The Azo-Dye Concept

The coupling of diazo-compounds with phenols to form an azo-dye is a well-established reaction. The possibility that a colored compound or dye could be produced by coupling pentachlorophenol with an aromatic amine was suggested by the junior author (6), and a series of investigations were initiated to test the hypothesis.

Although pentachlorophenol is a completely substituted phenol, there is a good possibility that it can be used to form an azo-dye. Saunders (13) states ". . . so great is the energy available for the consummation of the coupling reaction, that substitutes occupying positions to which the azo-link would normally attach itself in benzanoid rings are sometimes ejected, and the azo-compound is formed despite the blocking group." However, not only is pentachlorophenol a completely substituted molecule, but also it is negatively substituted, which makes the possibility of coupling even more remote. That a halogen atom can be ejected has been shown by Hewitt (5) who coupled α-bromo-naphthol with the loss of the bromine atom. An aromatic amine with peculiar properties was needed, therefore, to bring about the desired reaction.

WHAT THIS RESEARCH MEANS

A simple, economical, easily applied method that will clearly and precisely define the distribution of pentachlorophenol (not the solvent) in wood treated against organic deterioration is needed.

This report discusses the possibilities of coupling pentachlorophenol with an aromatic amine to form a colored compound in treated wood. The results of testing several amines for color reactions and the limitations of the technique are presented.

The authors also discovered that diazotized o-chloroaniline may be useful in differentiating between sapwood and heartwood.

Diazotized Amines Tested for Color Reaction

Table 1 lists 18 aromatic amines their molecular weights, and the method by which each of them was diazotized. The diazotization process was based upon the reaction:

$$ArNH_2 + HX + HNO \longrightarrow ArN_2X + 2\,H_2O$$

in which a solution of a metallic nitrite was added to a cold solution of the arylamine in aqueous mineral acid. The amines were selected to represent various types of molecular configuration and substituted groups.

The first two amines listed in Table 1, p-aminodimethylaniline and p-aminodiethylaniline, were diazotized by the "direct" method described by Saunders (13), whereas the sulfanilic acid was diazotized by the "inverted" method. The other compounds were diluted with small amounts of hot water before other chemicals were added in the direct method of diazotization.

A 0.01 molar aqueous solution of each compound was prepared. Ice was added to the aqueous solution, and the solution was allowed to stand for about 15 minutes. About 10 ml. of pentachlorophenol—95 percent ethyl alcohol solution containing 5 percent toxicant and 0.7 gm. of sodium hydroxide were mixed to form the sodium salt, sodium pentachlorophenate. To this solution was added ml. of the diazo-compound and the color reaction was observed. The results of the color tests are presented in Table 2.

Small wafers of eastern white pine were cold-soaked in a commercial pentachlorophenol solution, dried, and split along the grain. The diazo compounds were sprayed on freshly split surfaces of both treated and untreated wafers. The reactions were

Table 2.—COLOR REACTIONS OBTAINED UNDER BASIC AND ACIDIC CONDITIONS WITH DIAZOTIZED AMINES AND PENTACHLOROPHENOL

Diazotized compound[1]	Color test made: In vitro[2] Acidic	In vitro[2] Basic	On eastern white pine[3] Acidic	On eastern white pine[3] Basic	Test status based on color reactions
-aminodiethyl aniline	Strong pink	Strong green	No color	No color	Discontinue
-aminodiethylaniline	Strong pink	Strong green	No color	Weak green	Continue
-amino-2-naphthol-4-sulfonic acid	Weak amber	Strong amber	No color	No color	Discontinue
nthranilic acid	No color	Strong red-brown	No color	No color	Discontinue
-chloroaniline	No color	Weak pink-brown	No color	Weak orange	Continue
-chloroaniline	No color	Weak yellow	No color	Weak yellow	Continue
-bromoaniline	No color	Weak red-orange	No color	No color	Discontinue
-iodoaniline	Strong red-brown	Weak brown	No color	Weak brown	Continue
naphthylamine	Strong red-brown	Weak pink	No color	No color	Discontinue
-naphthylamine	Weak red	Strong orange	No color	Weak red	Continue
naphthylamine-4,8-disulfonic acid	No color	No color	No color	No color	Discontinue
naphthylamine-4,8-disulfonic acid	No color	Strong red	No color	Strong red	Continue
-naphtholamine-6-sulfonic acid	No color	Strong purple	No color	No color	Discontinue
-nitroaniline	Weak amber	Strong red	Weak[4]	Strong[4]	Continue
-nitroaniline	Weak clear yellow	Weak amber	No color	No color	Discontinue
-nitroaniline	Strong red-orange	Strong blood-red	No color	No color	Discontinue
nitroaniline-o-sulfonic acid	No color	Strong red	No color	No color	Discontinue
ilfanilic acid	No color	No color	No color	No color	Discontinue

[1] Diazotized compound prepared as outlined in Table 1.
[2] Diazotized amine mixed with pentachlorophenol-ethyl alcohol solution.
[3] Wood specimens cold-soaked in commercial pentachlorophenol and dried before diazotized amine applied.
[4] Missing data.

Table 3.—COLOR REACTIONS[1] OBTAINED UNDER BASIC AND ACIDIC CONDITIONS WITH FOUR CONCENTRATIONS OF DIAZOTIZED AMINES SPRAYED ON WHITE PINE TREATED WITH PENTACHLOROPHENOL

Diazotized amine	Dilution of 1/100 molar diazo-compound: None Acidic	None Basic	1:2 parts water Acidic	1:2 parts water Basic	1:10 parts water Acidic	1:10 parts water Basic	1:50 parts water Acidic	1:50 parts water Basic	Test status based on color reactions
p-aminodiethylaniline	Good[1]	Good	Poor	Fair	Poor	Good[1]	Poor	Fair	Continue
o-chloroaniline	Good[1]	Poor	Poor	Poor	Poor	Fair	Poor	Good[1]	Continue
p-chloroaniline	Poor	Poor	Poor	Fair	Poor	Fair[2]	Poor	Fair	Discontinue
p-iodoaniline	Poor	Poor	Poor	Fair	Poor	Poor	Poor	Poor	Discontinue
β-naphthylamine	Poor	Poor	Poor	[2]	Good	Fair	Poor	Poor	Discontinue
2-naphthylamine-4,8-disulfonic acid	Poor	Poor	Poor	Poor	Fair	Fair	Poor	Fair	Discontinue
m-nitroaniline	Poor	Poor	Fair	Poor	Poor	Fair	Poor	Fair	Discontinue

[1] Excellent differentiation between treated and untreated areas.
[2] Missing data.

Table 4.—COLOR REACTIONS OBTAINED UNDER ACID AND BASIC CONDITIONS WITH VARIOUS CENCENTRATIONS OF TWO DIAZO-COMPOUNDS SPRAYED ON WOOD TREATED WITH PENTACHLOROPHENOL

	Aqueous dilution of 1/100 molar diazo-compound: None A[1]	None B[2]	1:2 A	1:2 B	1:6 A	1:6 B	1:10 A	1:10 B	1:20 A	1:20 B	1:30 A	1:30 B	1:40 A	1:40 B	1:50 A	1:50 B	1:100 A	1:100 B	Test status
p-aminodiethylaniline	P[3]	P	NT[4]	P	NT	P	NT	P	NT	P	NT	P	NT	P	NT	P	NT	P	Discontinue
o-chloroaniline	NT	NT	NT	NT	NT	NT	NT	P	NT	P	NT	F[5]	NT	F	NT	F	NT	F	Continue

[1] A, acid conditions.
[2] B, basic conditions.
[3] P, poor color reaction.
[4] NT, not tested in this series.
[5] F, fair color reaction.

Table 5.—COLOR REACTIONS OBTAINED WITH DIAZOTIZED O-CHLORANILINE APPLIED UNDER ACIDIC AND BASIC CONDITIONS TO WHITE PINE SECTIONS CUT FROM WOOD TREATED WITH PENTACHLOROPHENOL

Pine section: Number	Pine section: Treatment before o-chloroaniline applied	Dilution of diazotized o-chloroaniline H_2O	Method[1] of diazotizing o-chloroaniline	Reaction observed 12 hours after diazo-compound applied
1	None	Conc.[2]	Direct	Heart-sap differentiation; poor color
2	None	Conc.	Direct	Color poor, but encouraging
3	Soaked 1 min. in Na_2CO_3; dried	1:40	Direct	No color
4	Soaked 1 min. in $N1_2CO_3$; dried	1:100	Direct	Heart-sap differentiation; poor color
5	Sprayed with Na_2CO_3; not dried	1:40	Direct	Color poor, but encouraging
6	Sprayed with Na_2CO_3; not dried	1:100	Direct	Heart-sap differentiation; poor color
7	Soaked 1 min. in Na_2CO_3; dried	1:40	Indirect	Heart-sap differentiation; poor color
8	Soaked 1 min. in Na_2CO_3; dried	1:100	Indirect	Heart-sap differentiation; poor color
9	None	Conc.	Indirect	Color poor but encouraging
10	None	Conc.	Indirect	No color
11	Sprayed with Na_2CO_3; not dried	1:40	Indirect	Color poor but encouraging
12	Sprayed with Na_2CO_3; not dried	1:100	Indirect	Heart-sap differentiation; poor color
13	None	1:40	Direct	Heart-sap differentiation; poor color
14	Soaked 1 min. in Na_2CO_3; dried	Conc.	Direct	Color poor but encouraging
15	None	Conc.	Direct	Color poor
16	None	Conc.	Indirect	Color poor
17	None	Conc.	Direct	Color poor
18	None	Conc.	Direct	Color poor but encouraging
19	None	Conc.	Indirect	Color poor but encouraging

[1] See Table 1.
[2] Concentrated, or 1/100 molar solution.

observed under both acidic and basic conditions. The diazo-amines were acidic; basic conditions were obtained by spraying the wood with an aqueous 5 percent solution of sodium carbonate before the diazo-compound was applied.

The following compounds were selected for additional tests because they showed reasonably good color reactions: p-aminodiethylaniline; o-chloroaniline; p-chloroaniline; p-iodoaniline; β-naphthylamine; 2-naphthylamine-4,-8-disulfonic acid; m-nitroaniline.

A 0.01 molar solution of each of the seven diazo-compounds was prepared. The "concentrated" solution as well as three aqueous dilutions of it were applied to small wafers of white pine cut from stock which had been cold-soaked in a commercial solution of pentachlorophenol. The dilutions were: 1 part diazo-compound: 2 parts water; 1 part diazo-compound: 10 parts water; 1 part diazo-compound: 50 parts water.

The liquids were sprayed on the wood wafers, and the color reactions obtained under basic and acidic conditions were noted (Table 3). The color reactions obtained with p-aminodiethylaniline and o-chloroaniline were encouraging and additional tests of these two compounds were initiated. Testing the other five compounds was discontinued because of the poor color reactions they gave.

Eight aqueous dilutions of 0.01 molar "concentrates" of diazotized p-aminodiethylaniline and o-chloroaniline were prepared. The dilutions used and the color reactions they gave are presented in Table 4. As a result of these tests, p-aminodiethylaniline was abandoned from further tests because of the relatively poor color reactions it gave. Although the tests of o-chloroaniline were not completely satisfactory (color was neither vivid nor consistently reproducible), the color reactions were good enough to warrant further testing of the compound.

Further Tests With Ortho-chloroaniline

A fresh supply of o-chloroaniline was diazotized by both the direct and inverted methods described in Table 1. Three concentrations of the diazotized compound were applied to sections of white pine which had been freshly cut from a post previously cold-soaked for 12 hours in a commercial solution of pentachlorophenol. The two aqueous dilutions of the 0.01 molar diazo-compound were: 1:40 and 1:100. The liquids were sprayed on the wood sections, some of which previously had been soaked or sprayed with a 5 percent aqueous solution of sodium carbonate. Some of the sections treated with sodium carbonate were oven-dried before they were sprayed with the diazotized o-chloroaniline, whereas others were treated immediately after they were sprayed with the sodium carbonate solution. Tests on wood sprayed with sodium carbonate were classified as being tested under "basic conditions," otherwise the test conditions were "acidic."

Table 5 shows the color reactions obtained with diazotized o-chloroaniline under specified conditions of test. Although the color reactions generally were poor, some results were encouraging. One interesting and unexpected result was the discovery that diazotized o-chloroaniline often differentiated between heartwood and sapwood.

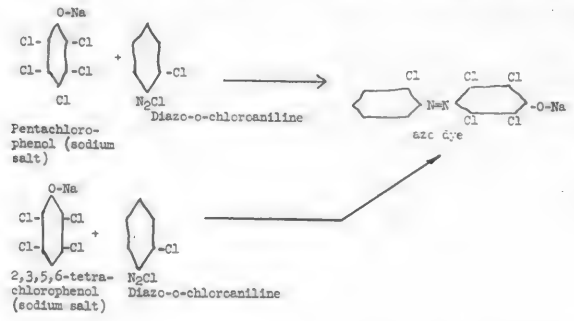
Effect of Light Spectra

A number of white pine samples used in the tests described above were observed under light of different wave lengths. Only those sections of pine that had given some indication of a color reaction (Table 2) and those showing a heart-sap differentiation (Table 5) were tested. A series of aqueous solutions of diazotized o-chloroaniline, some of which also contained pentachlorophenol, also were examined under different wave lengths of reflected light.

The wood sections and solutions were viewed under a mercury arc lamp and at three ultra violet ranges: 2250–4200Å, 2950–4050Å, and 3150–3900Å. The 2250–4200Å range seemed to cause the best fluorescence, but the results were not encouraging and the technique was abandoned.

Compounds Chromatographed

A series of tests were designed to show by comparative chromatography that azo dyes of the same ultimate configuration would produce spots of identical partition coefficient and could be identified by comparing the results with tests of known compounds. For example, it was hypothesized that if pentachlorophenol were coupled with diazotized o-chloraniline and chlorine were displaced from the para position, an azo dye would be formed which would have the same partition coefficient as the dye created from 2, 3, 6-tetrachlorophenol. The following reactions illustrate this reaction:



Azo dyes were made by coupling d azotized o-nitroaniline with each the following phenols: 2,3,5,6-tetr chlorophenol; and pentachlorophen An excess of crystalline sodium aceta was added to the dilute sodium ca bonate solution as a stabilizer durir the coupling process (13).

The dyes were chromatographed strips of Whatman No. 2 filter pap 4 x 18½ inches with the fiber dire tion paralleling the length of the stri The strips were sprayed to fiber sat ration point with a 5 percent aqueou solution of sodium carbonate.

The azo dyes, usually diluted wit 95 percent ethyl alcohol, were spotted on a line drawn across one end of th paper strip. Three spots of dye we placed equidistantly apart on the line with a small capillary tube. The di-ameter of the spot was kept to a mini-mum. Where superimposing spotting was necessary, either to increase the concentration of a single dye or to create a synthetic mixture, each se-quence of spots was allowed to dry to prevent spreading of the spots.

The paper strips were developed in a closed chamber. A stainless steel cradle, suspended from the plate glass lid used to close the jar, supported a plastic trough which contained the organo-phase of the two-phase solvent system used to develop the papers. The aqueous-phase of the developing sys-tem was placed in the bottom of the chamber. The paper strips were hung in the chamber for an hour to allow the paper and the aqueous phase to reach equilibrium. The organo-phase was prepared in a separatory funnel and transferred to the trough through a hole in the lid of the chamber; the hole was then stoppered. Capillary ac-tion and gravity caused the solvent to pass down the filter paper carrying the spots of azo-dye. Each dye was car-ried to a location on the paper and deposited at this point in a color, and at a distance from the starting point peculiar to the dye's partition co-efficient.

Solvents Selected

The selection of solvents for the chromatographic tests was made on the basis of the solubility characteristics of the particular azo-dye under study. Organo-solvents were selected which would completely dissolve the dye. Water, of course, served as the non-soluble carrier. The water-organo ratio in the organo-phase of the two-phase developing system determined the extent to which a dye-spot moved down the paper and the compactness of the spot at the point where it was finally deposited.

The following solvent mixtures were tested: 1. 2-butanol-water; 2. 2-butanol-water-ethyl alcohol; 3. 1-butanol-water; 4. 1-butanol-water-benzene; 5. 1-butanol-water-ethyl alcohol; 6. Methyl ethyl ketone-water; 7. Benzene-water-ethyl alcohol.

Pilot tests indicated that mixtures 1, 3, and 4 were best suited for developing the dyes listed above. The 1-butanol-water-benzene mixture gave the best development, but each of the dyes showed the same partition coefficient. When the diazotized p-nitroaniline was developed, the same results were obtained as when phenols were mixed with the diazotized amine. In other words, the desired color-forming reaction had not occurred. The color that developed formed as a result of an internal reaction with the diazo-compound and not as a result of coupling with pentachlorophenol.

Several factors influenced the behavior of the two-phase system and the success or failure of the chromatographic separation. Temperature was a highly influential factor. A variation of a few degrees between the temperature of the liquid in the separatory funnel in which the organo-phase was prepared and the liquid in the developing chamber often upset the equilibrium of the developing system and caused the spots on the paper to disperse. The influence of the heat from a bunsen burner located approximately 10 feet from the developing chamber caused the spots on the strip closest to the heat source to disperse.

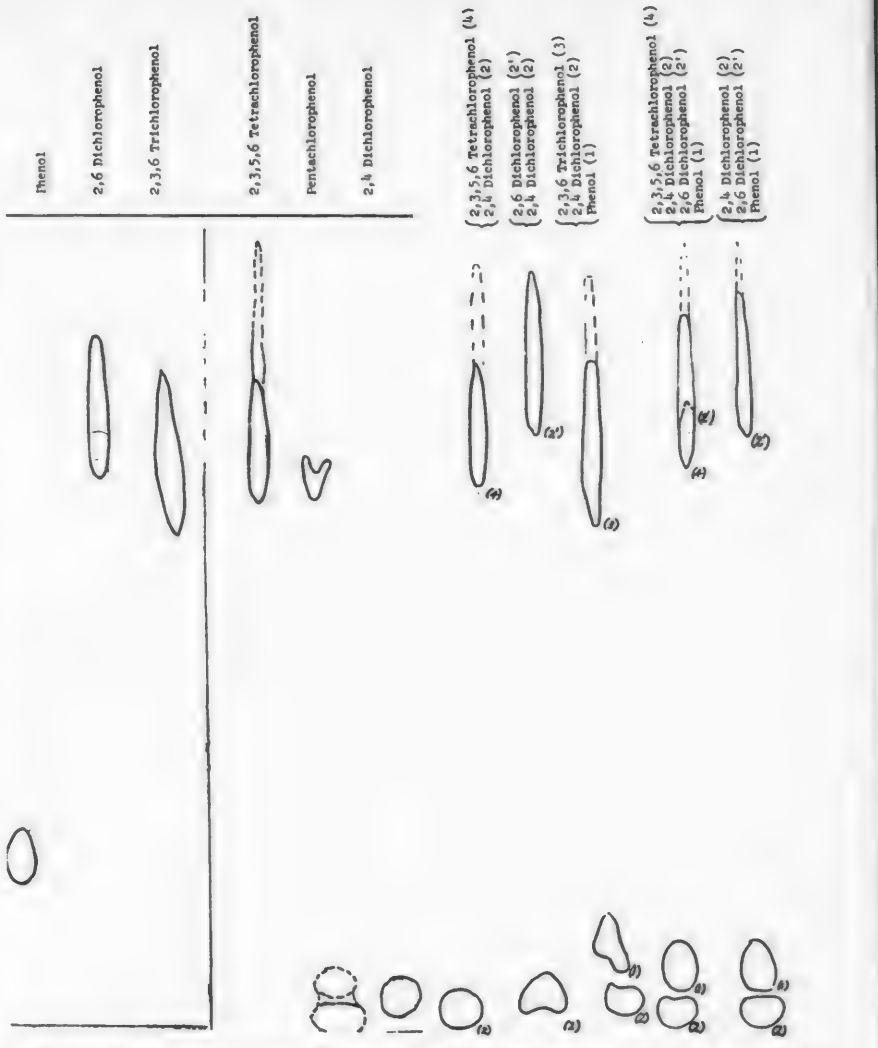


Fig. 1.—At left: chromatogram of single azo dyes formed from phenol and chlorinated phenols. Figure at right is chromatogram of synthetic mixtures of phenol and/or various chlorinated phenols. In each figure the main area of each spot is outlined with a solid line. Spots resulting from trailing and interfacial impurities are outlined with broken lines.

Picramide Tested

Meyer and Tochtermann (7) have indicated that 2,4,6-trinitrodiazobenzene (diazotized picramide) was such a strong coupling agent that it would attack the benzanoid hydrocarbon, mesitylene, to form an azo-dye.

A sample of picramide (2,4,6-trinitroaniline) was diazotized by Misslin's method (8) as follows: To a solution of the amine (7.1 gm.) in glacial acetic acid (125 gm.) at 15° C. was added dropwise a solution of sodium nitrite (2.1 gm.) in sulphuric acid (160 gm.). As the nitrosylsulfuric acid was added, the temperature was lowered, and finally a clear, yellow syrup was obtained at 3° C. The liquid was diluted with ice for synthetic reactions.

The diazotized picramide was then allowed to couple with each of the five phenols listed above, and the azo-compounds were chromatographed by procedures previously described. The chromatograms were developed with 2-butanol-water and 1-butanol-water solvents. A satisfactory color resulted from each of the phenols, but all the spots had the same partition coefficient as the control compound, diazo-picramide.

Orthochloroaniline Chromatographed

Two new diazotizing methods were tried on o-chloroaniline, namely, a modification of Schwalbe's direct method for chloronitroaniline, authorized by Saunders (13) and the Noelting-Kopp method (9) for 2-chloroaniline.

The modified Schwalbe method was as follows: The o-chloroaniline (10.5 gm.) was dissolved in warm 10N hydrochloric acid (25 ml.) diluted with water (25 ml.). When the compound was dissolved, the solution was cooled to 7° (± 2°) C. by pouring it on 100 gm. of ice. A solution of sodium nitrite (5.75 gm.) in water (40 ml.) was added and the two solutions stirred until clear.

The Noelting-Kopp method originally was used on 2-chloroaniline, but there was a good possibility that it might also yield satisfactory results with o-chloroaniline. Fifty milliliters of concentrated hydrochloric acid was diluted with water to 210 ml. and brought to a boil. A 0.1M solution of

the amine was prepared by adding 12.8 gm. of o-chloroaniline to the solution and the boiling continued until the molten base dissolved. The solution was cooled by stirring into ice until the temperature of the liquid had fallen to 10° C. At this temperature a solution of sodium nitrite prepared by dissolving 7 gm. of the salt in a minimum amount of water was added over a period of 30 seconds while the liquid was tsirred.

Each of the five phenols listed above, as well as 2,4-dichlorophenol, was tested with o-chloroaniline which had been diazotized by each of the two methods mentioned above. A spot of the diazotized o-chloroaniline was superimposed on a spot of each of the various chlorinated phenols which had been placed on the filter-paper strips. The strips were developed with the 2-butanol-water solvent.

Both methods of diazotization gave favorable color reactions with the phenols, the colors ranging from light yellow for phenol to a brownish purple for pentachlorophenol. The Noelting-Kopp methods gave the sharpest color reaction and a very light colored blank when the diazotized amine was tested alone. An immediate dark brownish-purple color resulted when a drop of diazotized o-chloroaniline was added to a small amount of purified pentachlorophenol dissolved in dilute sodium carbonate. Sodium carbonate alone gave little or no color under the same test conditions. The color obtained with pentachlorophenol was lost, however, when an excess of the diazo-compound was added (the pH was lowered) or when the solution was diluted with alcohol.

Although the results appeared encouraging, the dyes followed the interface too closely and the difference between spots was not great enough to separate the compounds. The dyes apparently were too soluble in the solvent being used, and a number of attemps were made to increase the amount of water in the developing system by the addition of ethyl alcohol. The results were not successful, and a methyl ethyl ketone-water-ethyl alcohol system was tried with no better results.

Solid Azo-Phenols Isolated

The possibility of isolating solid azo-phenols and determining their solubility in several organic solvents was tested.

Azo-phenols were prepared as follows: Approximately 1 gm. of phenol dissolved in a minimum of ethyl alcohol and 10 ml. of diazotized o-chloroaniline salt were combined and a 5 percent sodium carbonate solution was added to the solution until the liquid was basic to litmus. The bright red precipitate which formed when the mixture of compounds was stored overnight in a refrigerator was filtered and air-dried.

To 1.024 gm. of 2,4-dichlorophenol dissolved in a minimum volume of 95 percent ethyl alcohol was added 10 ml. of diazotized o-chloroaniline. The mixture was allowed to stand for several minutes before 15 ml. of 5 percent sodium carbonate was added, or until the liquid was basic to litmus. An immediate precipitate occurred. The orange-red precipitate was filtered and air-dried.

The azo-compound obtained from 2,6-dichlorophenol was prepared in the same way as that obtained from 2,4-dichlorophenol. The precipitate was dark red, however.

To 0.6331 gm. of 2,3,6-trichlorophenol dissolved in a minimum of ethyl alcohol was added 10 ml. of diazotized o-chloroaniline. Several minutes later, 20 ml. of 5 percent sodium carbonate solution was added to make the liquid basic to litmus. Again the mixture was allowed to stand several minutes, then concentrated hydrochloric acid was added until a precipitate formed. The dark red precipitate was filtered and air-dried.

The diazo-compound made from 2,3,5,6-tetrachlorophenol was prepared in much the same fashion as were the others. To 0.2236 gm. of the chlorinated phenol in a minimum volume of ethyl alcohol was added 5 ml. of diazotized o-chloroaniline and 20 ml. of 5 percent sodium carbonate. Thirty minutes later concentrated hydrochloric acid was added until a red, flocculent precipitate developed. The precipitate was filtered and air-dried.

Pentachlorophenol (1.8061 gm.) was dissolved in a minimum of ethyl alcohol and 15 ml. of diazotized o-chloroaniline were added. Then the liquid was made basic with 20 ml. of 5 percent sodium carbonate. The heavy, brownish purple precipitate which developed immediately was stored overnight in a refrigerator before it was filtered and dried.

Solubility tests were run on the solid azo-dyes as well as the chlorinated phenols. Benzene provided the most suitable vehicle, since it dissolved the compounds without modifying their color characteristics. The problem, however, was to introduce the non-solvent phase of the two-phase developing system, since water is not soluble in benzene. This was accomplished by adding ethyl alcohol in which both benzene and water are soluble. The amount of ethyl alcohol needed was determined by shaking equal portions of benzene and water in a separatory funnel, then adding ethyl alcohol until the upper layer began to clear. The alcohol: benzene: water ratio was found to be approximately 1:1:1.

The water-benzene-alcohol developer gave highly satisfactory results. Each of the azo-phenols established a distinct partition coefficient which, relatively speaking, was reproducible. It was possible to separate the phenols and to compare the dye from pentachlorophenol with those prepared from the other chlorinated phenols.

The chromatographic comparison the azo-dye from pentachlorophenol with that from 2,3,5,6-tetrachlorophenol supported the hypothesis that the coupling reaction had gone in the assumed direction; namely, that chlorine was displaced from the para position of the pentachlorophenol molecule and the diazotized o-chloroaniline was coupled at this position, thus giving the same partition coefficient as the dye created from 2,3,5,6-tetrachlorophenol. Identical spots were obtained by chromatographing these two dyes.

The clearest, most reproducible chromatographic results from pentachlorophenol were obtained by forming the dye directly on the paper, i.e. by placing pure pentachlorophenol dissolved in ethyl alcohol on the sodium carbonate-treated paper and superimposing a spot of the diazo-compound at the same location.

When the solid azo-dye was prepared from pentachlorophenol in the fashion described earlier (fifth paragraph above) and then dissolved in alcohol prior to spotting it on the paper, much of the original color seemed to dissipate even though it was apparent that the spot was comparable to the one obtained from tetrachlorophenol. The spot's color was often very light and sometimes after drying it could not be seen at all. A reasonable explanation for the interfacial spot is that either unreacted material was present or some internal or double-coupling reaction occurred. The later possibility is a common occurrence in azo-dye reactions, particularly when the pH is not closely controlled.

In any event when purified (triple recrystallized) pentachlorophenol was used, a definite color reaction was obtained that was different than the color reaction obtained with other chlorinated phenols. There was sufficient evidence to conclude that the color was partly due to a reaction which displaced chlorine from the para position on the pentachlorophenol molecule and that an azo-dye was formed that was comparable to the dye formed when 2,3,5,6-tetrachlorophenol was used in place of the pentachlorophenol.

The authors found that certain p

itions had to be observed in performing the tests; namely,

1. The diazotized o-chloroaniline had to be refrigerated at all times with the exception of the short periods of use when it was mixed with other chemicals. The compound deteriorated at temperatures above 10° C. One of the products of deterioration is phenol. The production of phenol can cause internal coupling, thereby creating results from which the investigator may draw false conclusions.

2. Optimum pH conditions had to be maintained. The authors believe that a satisfactory pH level can be maintained by introducing the acidic diazo-compound to sodium pentachlorophenate with enough excess base to neutralize the diazo-compound. The same condition was observed when testing for pentachlorophenol in wood.

Tests on Wood Replicated

Following the chromatograph investigations and the refinement of testing procedures, small samples of Norway spruce, southern pine, and basswood were treated with diazotized o-chloroaniline. The southern pine had been cold-soaked for 24 hours in a commercial pentachlorophenol solution. The spruce samples were extracted in a series of solvents: 95 percent ethyl alcohol, benzene, water, and ethyl alcohol. The samples were then given several brush applications of a commercilal solution of pentacholorophenol containing 5 percent toxicant. The basswood was cold-soaked 48 hours in pentacholorophenol solutions, one commercially prepared and one compound with diacetone alcohol as a solvent.

The samples of treated spruce and pine were brushed with a 5 percent aqueous solution of sodium carbonate or soaked in the solution for one hour. Diazotized o-chloroaniline was brushed on the samples immediately after the sodium carbonate solution was applied, and some were brushed after the sodium carbonate had dried for an hour. Some change in color occurred, indicating that the coupling reaction had taken place, but the reddish color was neither vivid nor distinct.

The diazotized o-chloroaniline was sprayed on the samples of treated basswood. A distinct change in color developed in the area in which pentachlorophenol should have been present, with the region penetrated by the pentachlorophenol turning a brownish-yellow, whereas the untreated area was yellowish. The results, however, were not distinctly superior to other methods of assaying penetration that are already in use. The results indicated that the possibilities for forming a colored compound by coupling pentachlorophenol with a diazotized amine were good. No plans for testing other amines have been made, however.

Summary and Conclusions

Because pentachlorophenol is highly toxic to fungi and insects, it is widely used as a wood preservative. The light color of the compound, however, makes qualitative assay of the treatment difficult. Several qualitative methods of analyzing the distribution of pentachlorophenol in wood have been described, but all of them have at least one objectionable feature. A method is needed that will clearly define the distribution of the toxicant, but not the solvent. The method must be practical for field use and reasonably simple and inexpensive to apply.

A hypothesis that an azo-dye, a colored compound, could be produced by coupling pentachlorophenol and a diazotized aromatic amine is presented. Eighteen amines of various molecular configurations and with different substituted groups were tested. The results of the tests were these:

1. Diazotized o-chloroaniline gave the best color reaction with pentachlorophenol.

2. A modification of the Noelting–Kopp method of diazotizing 2-chloroaniline proved the best way of diazotizing o-chloroaniline.

3. A 1:1:1 water-benzene-ethyl alcohol mixture gave the most satisfactory results as a developer in the chromatographic analyses.

4. Coupling pentachlorophenol and diazo-o-chloronaniline under basic conditions, that is, by spraying the chromatographic paper or wood specimens with sodium carbonate solution, appeared to improve the color of the azo-dye.

5. Identical spots and partition coefficients were obtained in the chromatographic analyses of azo-dyes from pentachlorophenol and 2,3,5,6-tetrachlorophenol.

6. The tests indicated that commercial grade pentachlorophenol contained impurities (other chlorinated phenols, for example) that affected the color reactions.

7. Certain precautions had to be observed in performing the chromatographic analyses and tests on wood; namely (a) the diazo-o-chloroaniline had to be stored under refrigeration with the exception of short periods when it was actually being used in the tests; (b) the compound deteriorated at temperatures above 10° C., thereby creating conditions which made it possible to draw false conclusions from the results; and (c) optimum pH conditions had to be maintained.

The authors concluded that:

1. Chlorine apparently was displaced from the para position on the pentachlorophenol molecule and the diazo-orthochloroaniline was coupled at this position, the same position open to coupling on the 2,3,5,6-tetrachlorophenol molecule.

2. A satisfactory pH level was maintained for the reaction by combining the acidic diazo-orthochloroaniline with the sodium salt of pentachlorophenol in the presence of an excess of sodium carbonate to neutralize the diazo-compound.

3. Diazotized o-chloroaniline has promise as a means of distinguishing between heartwood and sapwood.

4. The results of color tests on toxicant penetration in wood treated with pentachlorophenol through diazonium salt-phenol coupling reaction probably were not distinctly better than other methods currently used to assay preservative penetration.

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Allowable Loads for 8d Nails

BOTH REGULAR AND CLINCHED, DRIVEN THROUGH METAL SIDE PLATES INTO STRESS-GRADE LUMBER[1]

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Results of a series of tests using both regular and self-clinching 8d nails indicate allowable lateral resistance values and factors of safety according to various test methods.

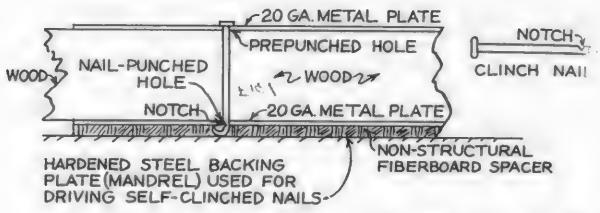


Fig. 1.—Cross-section showing how self-clinched nails are driven from top pre-punched plate through 1 5/8" wood member and bent back by driving against hardened steel plate.

TO DETERMINE THE ULTIMATE and allowable loads for eightpenny regular and self-clinched nails driven through 20-gage galvanized steel side plates into various species of commercial softwoods, a series of tests was conducted at the Structural Testing Laboratory of the University of Wisconsin. The tests were made on specimens cut from stress-grade 2 x 4 pieces of: 1) Douglas-fir (Coast Region), 1500f, Industrial Light Framing, air dried. 2) Southern Pine, No. 1, 1500f, air dried. 3) Douglas-fir (Inland Region), Standard Structural, air-dried. 4) Hemlock (West Coast), Construction Grade, kiln dried. All material was obtained from regular commercial suppliers, and was used in nominal 2-inch thickness.

The metal side plates were formed from 20-gauge A.S.T.M. A246, Grade "C" steel, galvanized before fabrication. Punched or drilled holes were used to facilitate easy nail starting and controlled nail spacing. Self-clinched nails punched their own holes in the far side plates and clinched back on the metal as shown in Fig. 1. Nails were regular, common type (10¼ gage); 8d by 1½ in galvanized; or 8d by 2¼ in. plastic cement coated, notched near the point for self-clinching.

Approximately fifty tests were made, all for lateral resistance of eightpenny (8d) nails driven through steel side plates into side grain of wood. Single, regular type 8d by 1½ in. nails were used in tests for about one-half of the specimens; single, notched 8d by 2¼ in. self-clinching nails were used for about one-third; and the remainder of the specimens involved multiple nail tests, both regular and clinch.

The test specimens were cut in two in the center and match marked so that the nails on each side of the joints were in wood of susbtantially equal characteristics for each test specimen. In selecting the wood tests specimens, wide ranges in ring counts, densities, and moisture contents were deliberately obtained. These ranged from 4½ to 41 rings per inch; 0.418 to 0.776 specific gravities; and 12 to 48 percent moisture. End distances ranged from 2⅛ in to 5½ in. For single-nail tests, production run H-BRACE connectors H–B No. 9 were used. For multiple-nailed specimens along the grain, spacing was 2 inches staggered. Across the grain spacing was 25/32 in. with a minimum edge distance of 7/16 in. Production run H-BRACE connectors No. 17 and 18 were used to provide these spacings with all nailing in prepunched holes.

Description of Tests

For each test the tension load was measured in increments of 50, 100, or 500 pounds from zero to ultimate on a 200,000 lb. capacity Universal Testing Machine, hydraulically operated, manufactured by Baldwin–Southwark. Dial gage reading on the testing machine were checked out by means of comparative loading with a standard proof-ring. Slip or deflection was measured on four 1-in throw Ames dial gages having a least reading of 1/1000 inch. Each dial gage was attached by two screws to a ⅛ inch thick steel plate 2 by 6 in. By means of C-clamps, two plates with attached gages were clamped on each side of the top of specimen as shown in Figs. 2 and 3. Like attachment of gages was made at the bottom of each specimen so that four dial gage readings were taken for each test piece. Two attachment bars, each ¼ by ½ by ¼ inches, were fastened to the center of metal side plates by means of sheet-metal screws as shown in Fig. 3. Attachment of dial stems to center bars was made by means of 32-gage B&S copper wires. The load was applied parallel to the axis of the specimens and substantially parallel to the grain at a uniform speed of 0.04 to 0.06 inch per minute, speed of head. Readings for a load-slip curve were taken at regular increments until the maximum load (ultimate) was obtained.

Single and double nail test specimens were prepared by inserting a 0.020-inch steel shimming strip under each metal side plate and driving the nails flush against the metal plate. After all nails were driven the steel shim plates were withdrawn. This procedure was used to reduce friction in the early part of the test and simulate shrinkage of lumber which would occur in use. Shimming strips were not used on clinch nail specimens.

All test specimens were attached in the testing machine with free end-bearings and accompanying devices, as shown in Fig. 2, to eliminate any eccentric action that might influence the results. The standard end-attachment devices consisting of two steel squares 1½ by 1½ by 18 inches, four steel linkage bars, two ¾-in. round steel pins, and four ¾-in. machine bolts were borrowed from the U. S. Forest Products Laboratory, Madison, Wisconsin. Universal joint action was obtained at each end because the steel pins held by the heads of the testing machine were oriented at right angles to the bolts going through the linkage bars and specimens. This method of

[1] A contributed article describing a test program sponsored by H-BRACE, Inc., Miami, Florida: Mr. Paul G. McKinley, General Manager, and Mr. Charles B. McAdam, Chief Engineer. The author served as consulting engineer to H-BRACE, with responsibility for developing and directing the test program. All tests were supervised by Prof. George W. Washa, Director of Materials Testing Laboratory, University of Wisconsin. Specific gravity and moisture determinations were made by the U. S. Forest Products Laboratory, Madison, Wisconsin.

sting was adopted to eliminate end straint, and was successful, as could e noted by the comparative double ial readings on each side of the ecimen.

Mulitple nail specimens shown in g. 5 were loaded through two 2⅝-. Teco Shear Plates with ¾-in. ma-ine bolts on each end of the speci-en. Dapped holes were cut by use a standard Greenlee cutting tool. should be noted that although more an recommended end distance (6 in. 5½ in.) and load capacity was ed for the multiple nail test speci-ens, the first test specimen failed by pull-out of the Shear Plates. This pe of failure was prevented in sub-equent tests by utilizing the C-clamps in the manner of stitch bolts to prevent tension across-the-grain splitting. Except for the heavily loaded multiple test pieces, all other specimens were attached to the heavy steel linkage bars by means of ¾-in. machine bolts as shown in Figs. 2 and 4.

Fig. 2.—Test set-up for single 8d by 1½ nail in 1⅝ by 1⅝ with one metal plate with single plane of stress transfer.

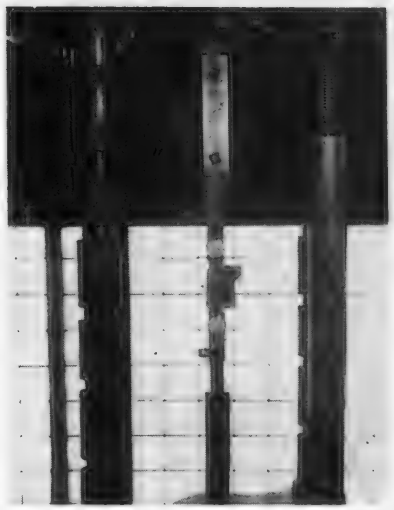


Fig. 3.—Test set-up for single 8d clinch or 8d by 1½ regular double nailed in 1⅝ by 1⅝ with metal side plates for two planes of stress transfer

Test Results

Summaries of test results are given in Tables 1 to 3. Values given for each species include nail type and size, ring count, moisture content, specific gravity, nail load at 0.015 inch slip, and ultimate load at failure. The average loads of front and rear gages for each test series are tabulated in the summaries. Detailed test data and load-slip curves for each series of five test specimens are not included in this article.

It has been determined in many tests over the years that holding ability of nails depends upon nail type and size, species and grade, moisture content, and specific gravity. When a nail joint is subjected to a longitudinal pull, the slip or deformation accompanying the load causes the joint to become useless sometime before the maximum load is reached. Tests on joints and fastenings show that the proportional limit load is the proper load which can be applied to the joint repeatedly without permanent injury. In the case of a nailed joint this proportional limit value is usually not well defined, hence an arbitrary value of 0.015-inch slip has been generally adopted as a standard by the U. S. Forest Products Laboratory and other authorities. Therefore, in these tests two sets of values are presented: utlimate or failure loads as determined from the maximum testing machine reading, and proportional limit values at a slip of 0.015-inch.

Composite load-slip curves for eightpenny (8d) nails in Douglas fir are shown in Fig. 6. Values plotted are from test results and are not adjusted to N. D. S. specific gravity. Note the smooth curvature for the three cases shown: single nailed, double nailed, and clinch nailed. These curves show the relationship between the single plane of stress transfer and the double planes of stress transfer. Increasing lateral resistance per nail is clearly indicated. Similar composite curves for 8d nails in Southern Pine are shown in Fig. 7.

Clinch Nail Values by Forest Products Laboratory Method

The Wood Handbook (1)[2] gives the standard procedure for establishing the allowable load for a common wire nail in lateral resistance when driven into the side grain (perpendicular to the wood fibers) of seasoned[3] wood:

$$p = KD^{3/2}$$

where p = allowable lateral load in pounds per nail
K = a constant, given in Table 27 (Reference *1*)
D = diameter of nail in inches

Values for K are obtained by dividing the constants in general formulas for the proportional limit loads of nailed joints in different species by a reduction factor of 1.6. The allowable lateral load for side-grain nailing given by the general formula applies whether the load is in a direction parallel to the grain of the pieces joined or at right angles to it.

The K-values in the Wood Handbook are somewhat different from the K-values given in the National Design Specification 2) (K = 1375 vs. K = 1650). Since N.D.S. equivalents are sought in the present test program, an adjustment was made to convert the Laboratory factor of 1.6 to the N.D.S. equivalent. This is done by multiplying the ratio 1375/1650 by 1.6 to get 1.33 as shown by computations in Table 4.

All ultimate and 0.015-slip values from test averages for the various cases have been converted to standard specific gravity (G) of 0.51 for Douglas-fir and 0.59 for Southern Pine as given in Appendix G of N.D.S. (2). This has been done by proportionality to $G^{3/2}$ in accordance with the procedure suggested by Mr. John Scholten, Engineer of the USFPL at Madison.

It should be noted in Table 4 that for eightpenny single nails with single plane of stress transfer, the gravity adjusted test value of 108 lb. per nail for Group "3" woods is in fairly close agreement with the N.D.S. value of 98 lb. per nail. The latter figure includes the 25 percent increase allowed for metal side plates. In fact, the test loads are approximately 10 percent higher than the N.D.S. allowable load. The lower clinch nail value determined by this method is 225 lb. per nail, with a reduction factor which is a ratio of 3.7 on maximum load.

Clinch Nail Values by Proportionality Method

Allowable clinch nail values may be determined by modifying the N.D.S. allowable loads for lateral resistance by the ratio Test Value Clinch Nail/ Test Value Regular Nail. Under this method, the allowable load is based

[2] Numbers in parentheses refer to the Literature Cited at the end of this paper.

[3] Moisture content of seasoned wood is defined on page 325 of Wood Handbook, "the minimum moisture content range of thoroughly air dry lumber is 12 to 15 percent, and the average is somewhat higher." Note that the moisture contents of test specimens used to establish allowables is in this range. See Tables 1 to 3.

Table 1.—DOUGLAS FIR (COAST REGION), 1500f, ILF, AIR DRIED-TEST RESULTS

Physical Properties

Specimen and Mark	Ring Count (per inch)	Nail Type and Size	Moisture Content	Specific Gravity[1]	Pounds: Nail Load at 0.015 Slip	Pounds: Ultimate Load at Fail
1F	22	8d Clinch Single Nail	16%	0.554	278	975
2F	12	in 1⅝" x 1⅝" Metal	14%	0.553	606	1000
3F	8	Side Plates and 2 Planes	24%	0.535	221	900
4F	8	of Stress Transfer	26%	0.533	292	975
5F	9	(Fig. 4)	16%	0.522	330	890
Average				0.539	346	948
6F	10/16	8d x 1½" Nail Double	15%	0.583	250	685
7F	16	Nailed in 1⅝" x 1⅝"	48%	0.432	265	575
8F	26	Metal Side Plates and	12%	0.424	206	525
9F	34	2 Planes of Stress	13%	0.442	329	585
10F	29	Transfer (Fig. 3)	12%	0.433	186	510
Average				0.463	247	576
11F	14	8d x 1½" Nail Single	13%	0.504	122	495
12F	8	Nail in 1⅝" x 1⅝"	12%	0.470	137	495
13F	41	Metal Side Plates and	13%	0.442	95	375
14F	12	Single Plane of Stress	13%	0.483	103	360
15F	13	Transfer (Fig. 2)	12%	0.447	205	485
Average				0.469	132	442

[1]Based on ovendry weight and volume determined by F. P. L.

Table 2.—SOUTHERN PINE, NO. 1, 1500f, AIR DRIED-TEST RESULTS

Physical Properties

Specimen and Mark	Ring Count (per inch)	Nail Type and Size	Moisture Content	Specific Gravity[1]	Pounds: Nail Load at 0.015" Slip	Pounds: Ultimate Load at Fail
1P	10/32	8d Clinch Single Nail	14%	0.639	475	1000
2P	13	in 1⅝" x 1⅝" Metal	14%	0.622	308	870
3P	14/30	Side Plates and 2 Planes	14%	0.704	362	950
4P	10	of Stress Transfer	14%	0.661	300	1000
5P	19		14%	0.751	311	1020
Average				0.675	351	968
6P	16	8d x 1½" Nail Double	14%	0.776	280	645
7P	19	Nailed in 1⅝" x 1⅝"	13%	0.572	275	488
8P	8	Metal Side Plates and	14%	0.649	271	400
9P	14	2 Planes of Stress	19%	0.770	257	390
10P	15	Transfer	13%	0.730	267	785
Average				0.699	270	542
11P	4	8d x 1½" Nail Single	13%	0.618	160	375
12P	6	Nail in 1⅝" x 1⅝"	14%	0.478	140	320
13P	10	Metal Side Plates and	15%	0.606	100	375
14P	5	Single Plane of Stress	13%	0.606	125	385
15P	12	Transfer	13%	0.682	154	400
21P	18		12%	0.539	152	320
Average				0.588	138	362
MP6		Comparative Metal Plates			Multiple Nailing	
Clinch	10/27	10 8d Clinch	13%	0.700	300	870
		vs.				
Regular	10/27	20 8d x 1½"	13%	0.700	231	435

[1]Based on ovendry weight and volume determined by F. P. L.

Table 3.—HEMLOCK (WEST COAST), CONSTRUCTION GRADE, KILN DRIED-TEST RESULTS

Physical Properties

Specimen and Mark	Ring Count (per inch)	Nail Type and Size	Moisture Content	Specific Gravity[1]	Pounds: Nail Load at 0.015" Slip	Pounds: Ultimate Load at Fail
1H	4	8d Clinch Single Nail	13%	0.480	254	800
2H	3	in 1⅝" x 1⅝" Metal	14%	0.449	307	925
3H	5	Side Plates and 2 Planes	12%	0.490	386	1080
4H	13	of Stress Transfer	15%	0.562	310	1160
5H	11		13%	0.418	206	990
Average				0.480	293	991
6H	25	8d x 1½" Nail Double	12%	0.569	225	625
7H	14	Nailed in 1⅝" x 1⅝"	14%	0.530	225	550
8H	22	Metal Side Plates and	12%	0.452	192	470
9H	14	2 Planes of Stress	14%	0.454	181	465
10H	4½	Transfer	14%	0.480	194	525
Average				0.498	203	527
Douglas Fir (Inland Region), Standard Structural, Air Dried						
1DFI	12	8d Clinch Multiple (10)	26%	0.518	192	700
2DFI	9	Nailed 2 x 4 Metal Side	43%	0.570	208	770
3DFI	32	Plates 20 ga. H. B. No.	23%	0.622	192	890
4DFI	9	18 2 Plantes of Stress	20%	0.497	169	830
5DFI	12	Transfer	25%	0.516	205	777
Average				0.545	193	793
Douglas Fir (Coast Region), 1500f, ILF, Air Dried						
MF6		Comparative Metal Plates			Multiple Nailing	
Clinch	17/34	10 8d Clinch	13%	0.533	288	825
		vs.				
Regular	17/34	20 8d x 1½"	13%	0.533	188	412

[1]Based on ovendry weight and volume determined by F. P. L.
[2]Two 2⅝" Shear Plates failed before developing ultimate on ten 8d clinch nails.

on the relationship of the clinched nail value to the conventional nail value times the present allowable lateral resistance value of the nail (N.D.S.), including a 25 percent increase for metal side plates as given in the Wood Handbook.

In order to be conservative, the controlling allowable load may be the lesser of the values computed above. Calculations shown in Table 5 are given in accordance with the proportionality method.

Summary and Recommendations

1) Composite load-slip curves, Fig. 6 for Douglas-fir and Fig. 7 for Southern Pine, show smooth, rational relationships indicating that the test data is consistent, sufficient, and leads to dependable conclusions.

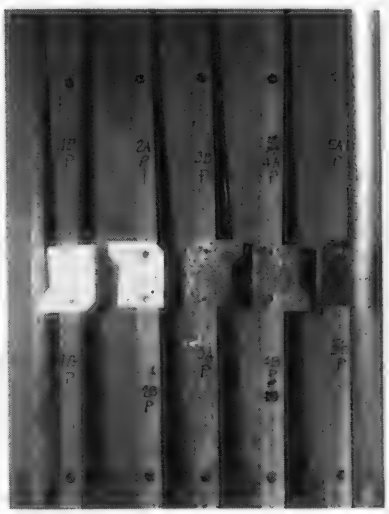


Fig. 4.—Side elevation of test specimens for single 8d clinch nail in 1⅝ by 1⅝ Southern Pine, two metal side plates with two planes of stress transfer.

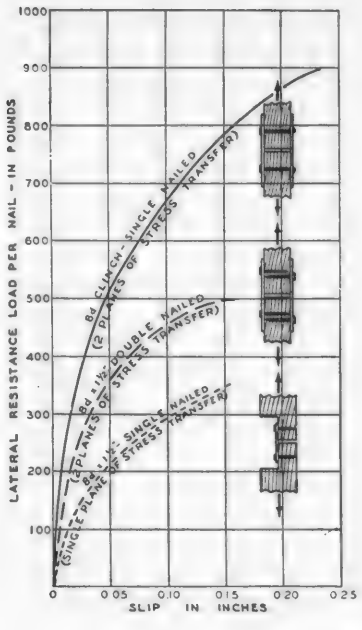
Fig. 5.—Side elevation of test specimens for 8d clinch multiple (10) nailed, 2 by Douglas fir (Inland Region) showing nail pull-outs and view of self-clinch anchorag

2) Summaries of test results and physical properties are given in Tables through 3.

3) No clear-cut exponential relationship between lateral resistance load (lb/nail) and specific gravity as reported in reference (3) could be established. However, adjustments to standard specific gravity were made by proportionality to $G^{3/2}$.

4) Allowable clinch nail values as calculated by the Forest Products Laboratory method and the proportionality method are within 8 percent of each other as shown in Tables 4 and 5.

5) A summary of allowable lateral resistance loads for eightpenny self-clinching nails is given in Table 6. Pending more extensive tests, a conservative interim metal side plate value of 175 pounds per nail, based on the lower range test values rather than the average, may be used for lateral resistance where nails are driven into


LATERAL RESISTANCE LOAD PER NAIL - IN POUNDS
SLIP IN INCHES
8d CLINCH - SINGLE NAILED (2 PLANES OF STRESS TRANSFER)
8d - 1½" DOUBLE NAILED (2 PLANES OF STRESS TRANSFER)
8d - 1½" SINGLE NAILED (SINGLE PLANE OF STRESS TRANSFER)

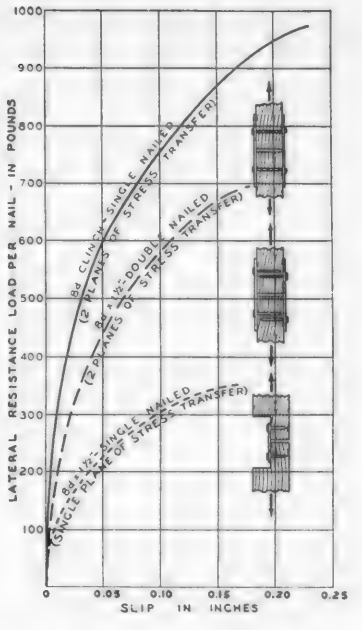

LATERAL RESISTANCE LOAD PER NAIL - IN POUNDS
SLIP IN INCHES
8d CLINCH - SINGLE NAILER (2 PLANES OF STRESS TRANSFER)
8d - 1½" DOUBLE NAILED (2 PLANES OF STRESS TRANSFER)
8d - 1½" SINGLE NAILED (SINGLE PLANE OF STRESS TRANSFER)

Fig. 6.—Composite Load-Slip curves for eightpenny nails in Douglas-fir (Coast Region). Each point on curve represents average value for five specimens plotted from test data for Load/Nail = 100, 150, . . .

Fig. 7.—Composite Load-Slip curves for eightpenny nails in Southern Pine. Each point on curve represents average value for five specimens plotted from test data for Load/Nail = 100, 150, . . .

MAXIMUM LOAD VALUES (ULTIMATE)

$$\text{Allowable clinch nail value} = \frac{\text{Ultimate Test Value of Clinch Nail}}{\text{Ultimate Test Value of Regular Nail}} \times \text{N.D.S. Allowable Load for Lateral Resistance}$$

or using

0.015-INCH SLIP LOAD VALUES (PROPORTIONAL LIMIT)

$$\text{Allowable clinch nail value} = \frac{\text{0.015-Slip Value of Clinch Nail}}{\text{0.015-Slip Value of Regular Nail}} \times \text{N.D.S. Allowable Load for Lateral Resistance}$$

Table 4.—ALLOWABLE 8d NAIL VALUES BY FOREST PRODUCTS LABORATORY METHOD

Nail Type	Specimen No.	Nail Load at 0.015" Slip from Tables 1 and 2	Reduction Factor Page 173, Ref. 1 $\frac{1375}{1650}$ (1.6) = 1.33	Allowable Lateral Nail Load
8d x 1½" Single Plane Douglas-fir	11F	122 #	1/1.33 = ¾	92 #/Nail
	12F	137	"	103
	13F	95	"	71
	14F	103	"	77
	15F	205	"	154
		Ave. Load for Douglas-fir	=	99 #/Nail
		Adjust to N.D.S. Std. Gravity from Appendix G and Table 1	$(99)\left(\frac{0.51}{0.47}\right)^{3/2}$ =	111 #/Nail
8d x 1½" Single Plane Southern Pine	11P	160	1/1.33 = ¾	120
	12P	140	"	105
	13P	100	"	75
	14P	125	"	94
	15P	154	"	116
	21P	152	"	114
		Ave. Load for Southern Pine	=	104 #/Nail
		Adjust to N.D.S. Std. Gravity	$(104)\left(\frac{0.59}{0.59}\right)^{3/2}$ =	104
		Ave. load for group "3" woods = ½(111 + 104)	=	108
		N.D.S. value with metal side plates = 78 (1.25)	=	98
8d Clinch Two Planes Douglas-fir	1F	278	1/1.33 = ¾	208
	2F	606	"	455
	3F	221	"	166
	4F	292	"	219
	5F	330	"	248
		Ave. Load for Douglas-fir	=	259 #/Nail
		Adjust to N.D.S. Std. Gravity	$(259)\left(\frac{0.51}{0.54}\right)^{3/2}$ =	238 #/Nail
8d Clinch Two Planes Southern Pine	1P	475	1/1.33 = ¾	356
	2P	308	"	231
	3P	362	"	272
	4P	300	"	225
	5P	311	"	233
		Ave. Load for Southern Pine	=	263 #/Nail
		Adjust to N.D.S. Std. Gravity	$(263)\left(\frac{0.59}{0.68}\right)^{3/2}$ =	212
		Ave. load for group "3" woods = ½(238+212)	=	225 #/Nail

Table 5.—ALLOWABLE 8d CLINCH NAIL VALUES BY PROPORTIONALLY-METHOD

$$\text{Allowable clinch nail value} = \frac{\text{Test value clinch nail}}{\text{Test value regular nail}} \text{ (N.D.S. Value)}$$

Value for 8d regular nail, Group 3, National Design Specification, Appendix f & Par. 800-E-3: 78(1.25) = 97.5, say 98 #/nail with 20 ga. metal side plates.

Lateral resistance at 0.015 inch slip

Douglas-fir
Test data from Table 1, adjusted for Standard Sp. Gr. from Appendix G:

$$\frac{346(0.51/0.54)^{3/2}}{132(0.51/0.47)^{3/2}} (98) = \frac{318}{148} (98) = 210 \text{ \#/nail}$$

Southern Pine
Test data from Table 2, adjusted for Standard Sp. Gr. from Appendix G:

$$\frac{351(0.59/0.68)^{3/2}}{138(0.59/0.59)^{3/2}} (98) = \frac{284}{138} (98) = 202 \text{ \#/nail}$$

Average for Group "3" woods = ½(210+202) = 206 #/nail

Lateral resistance at ultimate (failure) load

Douglas-fir

$$\frac{948(0.51/0.54)^{3/2}}{442(0.51/0.47)^{3/2}} (98) = \frac{872}{495} (98) = 173 \text{ \#/nail}$$

Southern Pine

$$\frac{968(0.59/0.68)^{3/2}}{362(0.59/0.59)^{3/2}} (98) = \frac{785}{362} (98) = 212 \text{ \#/nail}$$

Average for Group "3" woods = ½(173+212) = 192 #/nail
Assume **controlling** value at 0.015 inch slip or at ultimate whichever is the lesser. As shown above, controlling value based on ratio of ultimate lateral resistances is 192 pounds per eightpenny (8d) clinch nail with 20 gage metal side plates.

Table 6.—SUMMARY: ALLOWABLE LATERAL RESISTANCE VALUES FOR 8d SELF-CLINCHING NAILS WITH 20 GAGE METAL SIDE PLATES, GROUP 3 WOODS 1500f STRESS-GRADE DOUGLAS-FIR (COAST REGION) OR SOUTHERN PINE

		Factor of Safety (Ave. Ult. 828 #)
Forest Products Laboratory Method (0.015" Slip Basis)	225 lb. per nail	3.7
Proportionality Method (0.015" Slip Basis)	206 lb. per nail	4.0
Proportionality Method (Ultimate Basis)	192 lb. per nail	4.3
Conservative Interim Metal Side Plate Value	175 lb. per nail	4.7

1500f stress-grade Douglas-fir (Coast Region) and Southern Pine. This value is about 12 percent less than the value determined by the proportionality method, and about 25 percent less than that determined by the Forest Products Laboratory method, and results in a factor of safety of 4.7.

Literature Cited

1. Wood Handbook—Basic Information on Wood as a Material of Construction by Forest Products Laboratory, U. S. Department of Agriculture, 528 pp., 1955.
2. National Lumber Manufacturers Association, "National Design Specification for Stress-Grade Lumber and Its Fastenings," Washington, D. C., 70 pp., 1944, Revised and Amended 1957.
3. "Nail Holding Properties of Southern Hardwoods," by John A. Scholten, Reprint from Southern Lumberman, December 15, 1950.
4. "Light Wood Trusses," by R. F. Luxford, FPL Report No. 2113, 14 pages, 8 tables, 32 Figs., April 1958.

LOSS IN STIFFNESS EVALUATES DECAY RESISTANCE OF

Wood Treated with Copper Naphthenate[1]

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Inception of wood decay was measured by loss in stiffness of western white pine beams exposed to wood destroying fungi. Results of bending tests on material treated with copper naphthenate showed that a concentration of five percent by weight of copper applied by dipping inhibited most test organisms. Reduction in strength, indicated by increased deflection, showed failure of treatments often when there was no weight loss in the wood.

Fig. 1.—Loading device used to measure deflection of test beams resting upon glass racks and exposed to decay organisms in culture dishes. (Cover removed.)

Copper naphthenate is widely used as a wood preservative, particularly for boats and in marine installations. The compound is normally dissolved in light oil and applied as a surface treatment by brush or by dipping prior to setting the wood in place. Service records have shown that the preservative when used at a concentration of 3 percent by weight of copper metal generally gives good protection. Certain cases, however, have been reported—notably in enclosed spaces in boats—where decay occurred and where failure might have been attributable to variations in tolerance to copper of the specific fungus concerned.

Laboratory studies of the relative toxicity of fungicides in wood or of decay resistance of wood are commonly based on the computation of weight losses which occur as a result of decay in the material. When this procedure is used, only one aspect of decay, that is, the disintegration of structure or the final stage of fungal attack, is examined. In effect, however, decay is cumulative and its presence in wood may be detected at a much earlier stage, soon after its inception.

The fact that decay reduces the strength of wood is well known and this has been studied by many workers in relating results using mechanical tests to determine the extent of fungal deterioration.

Longyear (8),[2] using moist soil as inoculant, noted significant strength losses in wood samples before weight loss was measurable, also that the degree of loss varied widely with different wood species. In later work, employing specific fungi, Cartwright *et al* (1) and Scheffer *et al* (12) indicated that decay (brown rot) reduced all strength properties of wood and that toughness was affected at an early stage when weight loss was insignificant.

In 1954, Richards (11) concluded that, while toughness was a very sensitive indicator of decay in wood, values for this property were variable. Mulholland (10) reported that most changes in wood quality as a result of decay were first recorded in shock resistance, but that there was a downward trend in the modulus of elasticity after a short period of infection.

Mateus (9), employing static bending tests applied *in situ* to specimens exposed to decay, reported that bending strength was reduced rapidly, also that variations in results were reduced through the use of a non-destructive test during which the moisture of the wood was controlled.

When test material is placed in contact with cultures of decay organisms, infection commences at the periphery and deterioration is first apparent in this region. This reduces the effective dimensions of the piece to a degree equivalent to the extent of decay. Since the strength (stiffness) of a beam as indicated by its deflection under load varies directly as the width and as the cube of the depth (b d³

[1] A contribution (November, 1958) of the Vancouver Laboratory, Forest Products Laboratories of Canada, a Division of the Forestry Branch, Department of Northern Affairs and National Resources, Canada.

[2] Numbers in parentheses refer to the Literature Cited at the end of this paper.

measurements made periodically of the deflection of test pieces exposed to decay provide a means of indicating the progress of deterioration especially in the outer layers of the wood.

Toximetric studies of wood preservatives which are applied without pressure are concerned mainly with the fungicidal properties of the material deposited as a thin layer upon the surface. Failure of the treatment occurs when this covering is penetrated by the fungus; and, as this is accompanied by a progressive increase in deflection of the material, study of this relationship appears appropriate for treatments of this type.

Examination was accordingly made of the application of deflection tests as a means of detecting decay in wood specimens. This procedure was also used to determine the effectiveness of copper naphthenate dip treatments against fungi commonly associated with decay in marine structures.

Test Procedure

Solutions of copper naphthenate in varsol solvent were prepared in concentrations ranging from 0.5 to 5.0 percent by weight of copper and applied to the wood by dipping. The material was air-dried western white pine heartwood of uniform growth rate averaging 20 rings per inch and free from all defects. This was cut in the form of small beams 12 cm. long and accurately planed to 4 x 7 mm. in cross-section so that the annual rings were perpendicular to the narrow face.

After obtaining their oven-dry weight, the moisture content of the beams was increased to approximately 80 percent by submerging them in water. On removal they were surface-dried and immediately weighed before being dipped in the preservative at the required concentration for 15 seconds. Finally the average retention of copper as metal was computed for each test series by reweighing, after which the beams were sterilized in the autoclave.

Decay chambers used in the test were shallow dishes 25 x 15 x 5 cm., into which U-shaped glass supports formed of 10 mm. glass tubing and measuring 10 cm. across the arms, were placed resting flat upon the bottom. Malt agar medium (2.5 percent malt) was poured into each dish to a depth of 6 mm. and subsequently inoculated at several points across the surface with plantings of the decay organism.

A total of six fungi was included, namely, *Poria monticola, P. xantha, P. incrassata, Fomes roseus. Lenzites saepiaria* and *L. trabea.* After a suitable incubation period, when mycelial growth covered the agar surface within the rack, test beams were placed across the arms in contact with the fungus and with the narrow face uppermost. A total of 20 beams, 10 treated and 10 controls, arranged alternately, was contained in each dish.

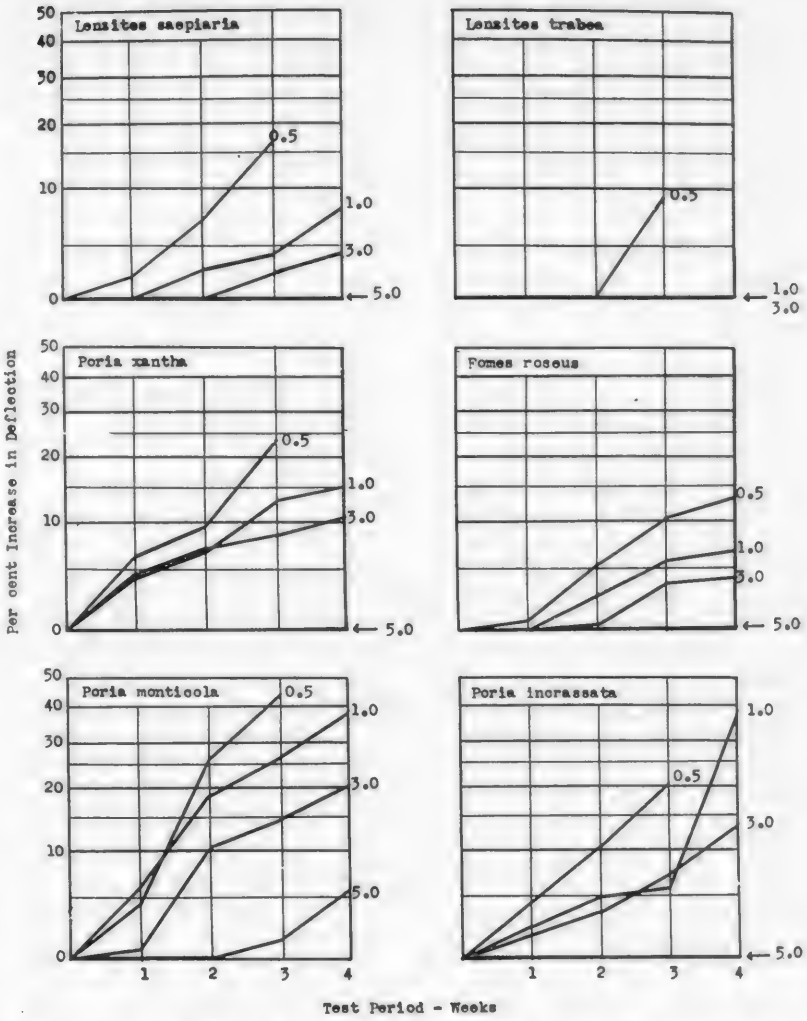

Fig. 2.—Loss of stiffness in wood beams treated with copper naphthenate, tested in static bending during exposure to decay organisms. Numbers at right of graphs refer to percentage of copper used in treatments by dipping.

Before returning the dish to the incubator, each beam was subjected *(in situ)* to static bending under a load of fixed value (1.6 kg.). Its initial deflection was read from a dial micrometer positioned between the beam and the load (Fig. 1) following a technique adapted from that of Mateus (9).

At weekly intervals during the four-week decay period, the deflection of each beam was again measured in a similar manner and these values expressed as a percentage of the original reading. At each observation, the cover for the culture dish was replaced aseptically with two smaller glass plates. When parted slightly these permitted insertion of the metal rod from the loading apparatus with a minimum risk of contamination to the culture.

Throughout the period the moisture content of the beams was in excess of 40 percent, so that variations in strength of the wood, related to moisture content, were avoided. There was, however, a tendency for the deflections to increase slightly with time as the beams were periodically subjected to the load (regardless of decay) so that observations were made of this factor.

In tests which paralleled the decay studies, sterilized beams without the decay culture were loaded in a similar manner and average weekly readings recorded. These were applied to the strength values obtained for infected material and gave the net figures for increase in deflection which are reported herein.

The effectiveness of treatments and total inhibition of decay was established in regard to the specific fungus concerned, when the increase in deflection of treated beams in culture during four weeks' exposure was less than that recorded for uninfected material tested over the same period.

Results

As indicated in the Table, relatively high concentrations of copper naphthenate applied to western white pine were required to prevent decay by the test fungi. Only *Lenzites trabea* was inhibited at the 3 percent level, while for the remainder, with the exception of *Poria monticola,* a 5 percent solution (by weight of copper) was necessary. In beams treated at the lower concentrations where the solution proved to be non-toxic, the rate of deflection increased rapidly (Fig. 2) once decay was established.

The calculated weight of copper metal retained by the wood was fairly uniform in all cases; for the 3 percent solutions the figure was .002 pounds per square foot and .004 pounds for the 5 percent dips. By means of soaking beans for one-half hour in a 3 percent solution heated to 70° F. in a subsequent test, a retention of .009 pounds of copper per square foot was obtained. This treatment proved to be toxic to *Poria monticola.*

A total of 20 beams was used in each of the 30 test series, and the initial deflections recorded in static bending, before decay, ranged between .017 and .024 inches. For material which was not subjected to decay but loaded at intervals for a period of one month, deflections increased, as compared with the initial reading, by approximately one percent per week.

In tests where decay occurred, the deflection values for the beams increased rapidly, particularly where copper-tolerant fungi were involved. Increases in the net deflection of up to 12 percent for untreated beams and up to 6 percent for treated material were recorded after one week's exposure. When deflections increased beyond 100 percent, breakage usually occurred, but readings which approached this value were only observed in untreated beams.

The preservative had a depressing effect upon growth of the test fungi in plate cultures. This resulted in a lower rate of decay in untreated controls when the copper content in adjacent treated members was increased in successive test series. At the highest concentrations, however, when decay was inhibited in the latter material, measurable increases in deflection, indicating surface deterioration, were always recorded in the controls.

At the end of each test, weight losses resulting from decay in the wood, were determined. Employing this procedure as an indication of toxicity, treatments of 3 percent by weight of copper appeared to inhibit practically all decay in the beams with the exception of that caused by *Poria monticola.* Weight losses of less than one percent were observed in the case of beams treated with the one percent solution when decayed by *Fomes roseus, Lenzites saepiaria* and *L. trabea* after a period of one month.

In the case of both *P. incrassata* and *P. xantha* in the latter test series, while weight losses from decay in the beams were less than 0.3 percent, deflections increased in the same period by 13.5 and 10.9 percent respectively of that observed in sound wood. For the remainder, in tests where no weight loss was apparent, the ultimate loss in strength was not as great, but there was a consistent increase in deflection observed throughout the period, and the onset of decay was established.

Discussion

The use of this technique in obtaining strength measurements in wood test material provided a sensitive means of indicating the advent of decay. Since these values were obtainable at intervals during the exposure period without destroying the material as a consequence, a relatively small number of specimens was required in each test.

In preparing material for testing in static bending, it was essential that the wood remain above the fibre saturation point. To insure this condition, all beams were soaked in water before being dipped in the copper naphthenate. In normal procedure, however, wood material is seasoned before being dipped to obtain maximum penetration of the preservative, but in the test this condition was controlled by other means.

Considering that wood is not homogeneous, a certain lack of uniformity in the strength of beams was to be expected. Despite the fact that material was carefully selected, the initial deflection recorded for certain beams was somewhat higher than for others. Sufficient tests were also carried out to estabilish that this difference in strength between beams was maintained during the decay process. In order to assess the decay damage, therefore, in any one test series, the deflection of each individual beam was recorded weekly as a percentage of its original value which provided a common base for comparison.

For most tests wherever a small increase in the deflection of beams was recorded at the end of the second week, it was found that this figure increased markedly by the end of the period and it was thus readily apparent that the treatment was non-toxic. Exceptions occurred in the case of both *Lenzites saepiaria* and *L. trabea* where the effects of decay were not apparent in certain tests until the third week.

Employing the former organism, however, deflections of beams treated at the three percent level were of sufficient magnitude that the need for further tests at a higher level was unquestionable. For *L. trabea,* as the increased deflections in material treated at the one percent level of concentration were small, it is probable that the toxic point for this fungus was closer to this figure than to that of three percent. The final test of the latter concentration was, however, carried out to conform to the original procedure.

The fact that certain fungi vary in their tolerance to copper in preservatives has been previously reported (2, 3,4,5,7,13,14), and in these tests, the extent of decay was usually measured by the weight loss method. Values reported for these previous tests are generally similar to those presently reported using the weight basis although Cowling (3) indicated that *Poria incrassata* was more tolerant than indicated here.

Upon comparison of the merits of the two laboratory procedures, one based on weight loss, the other on loss in strength properties, each method appears to have its own application.

Using the techniques described herein, results are obtainable in a very short period as compared with the weight loss method. As the test fungi are grown upon malt agar, however (which offers no resistance to subsequent bending of the test beam), the procedure does not lend itself to a test of the permanency of preservative treatments as there is a high loss of moisture from the subtrate. Using a more solid medium (such as sterilized soil) and vented culture jars (6) which retain moisture and sustain fungal growth for longer periods, tests may be extended indefinitely.

When the weight loss method is used as an indication of decay, the entire mass of material must be taken into account, regardless of whether all parts of the wood are affected. In the case of toximetric studies of preservatives applied without pressure, only the surface layers of the wood which receive the treatment are directly concerned.

As this thin skin is normally but a small proportion of the total mass of the test piece, its destruction by decay may not appreciably affect the total weight. Significant weight losses cannot be expected to occur, therefore, until some time has elapsed and until decay has not only attacked the treated layer but has also penetrated this surface and resulted in deterioration of the untreated inner portion. In this case the rate of decay as measured by weight is largely a measure of the rate of spread of the fungus within the sub-surface layers, which is of slight concern in studies of preservatives applied to the outer surface. For studies

o indicate the effectiveness of non-pressure treatments, therefore, the trength loss method which relates to he conditions at the surface of the ood appears applicable.

In other cases, however, where the xicity of preservatives applied under ressure is concerned or in studies of he natural durability of wood species, is necessary to examine the material n its entirety. In such studies, particularly in tests of preservatives where eep penetration has been obtained in he wood, loss of weight from decay ppears to be a more appropriate test. hus in comparing the natural durability of woods either method can be sed to advantage.

Summary

Examination was made of the use of a strength test to indicate the advance of decay in wood. At weekly intervals, marked increases in the rate of deflection were recorded in small beams exposed to cultures of wood-destroying fungi and subjected *in situ* to an intermittent load of fixed value. A small continuing increase in deflection was noted in uninfected material loaded similarly but this rate was much less than that for partly decayed specimens.

Results obtained in the above tests using western white pine heartwood treated by dipping in solutions of copper naphthenate indicated that a high concentration of the preservative was required to inhibit certain fungi associated with decay in boats.

Lenzites trabea was inhibited at the 3 percent level (by weight of copper metal) with a retention of .002 pounds of copper per square foot, followed in order of tolerance by *L. saepiaria, Fomes roseus, Poria xantha* and *P. incrassata,* inhibited at 5 percent. (.004 pounds per square foot). A retention of .009 pounds per square foot was required to inhibit decay by *P. monticola.*

The strength loss method appeared applicable for use in toxicity tests of wood preservatives which are to be applied without pressure. It was also more sensitive to the presence of early decay in wood than that which involves the measure of weight loss.

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Toxicity of Copper Naphthenate in Tests Based on Loss of Stiffness and of Weight in Treated Wood Beams Exposed to Decay in the Laboratory[1]

Organism	Treated beams: Concentration of copper in varsol solution (per cent)	Treated beams: Retention of copper in wood beams (lb./sq.ft.)	Average per cent net increase in deflection of 10 beams under a load of fixed value applied weekly during decay test: 1 Week T	1 Week U	2 Weeks T	2 Weeks U	3 Weeks T	3 Weeks U	4 Weeks T	4 Weeks U	Final Weight Loss (per cent): T	Final Weight Loss (per cent): U[2]
Poria monticola	0.5	0.0002	4.1	7.7	26.0	39.5	44.0	57.8	-	-	6.9	9.6
	1.0	.0006	6.0	11.7	18.4	41.6	26.4	98.4	38.1	B[3]	2.1	18.0
	3.0	.002	0.7	11.6	10.5	34.6	14.3	69.4	20.4	B	0.3	16.2
	5.0	.004	0	2.7	0	8.9	1.6	15.9	5.7	32.4	3.2	10.5
	3.0*	.009	0	6.5	0	43.2	0	59.2	0	B	0	18.0
Poria incrassata	0.5	.0002	4.5	7.3	10.3	22.9	20.5	38.9	-	-	2.8	7.9
	1.0	.0004	2.3	6.0	5.0	14.4	5.8	46.6	38.3	B	2.4	14.5
	3.0	.002	1.3	11.8	3.5	15.3	7.0	20.7	13.5	45.7	0.2	7.4
	5.0	.004	0	7.5	0	7.3	0	10.4	0	22.9	0	10.8
Poria xantha	0.5	.0002	6.2	4.5	9.2	9.1	23.2	24.0	-	-	2.2	2.2
	1.0	.0005	4.2	8.8	6.6	16.5	13.1	26.9	14.8	39.1	1.4	10.6
	3.0	.002	4.1	7.1	6.7	10.3	8.6	5.2	10.9	24.0	0	2.0
	5.0	.004	0	0.6	0	0	0	0	0	1.0	0	0.3
Fomes roseus	0.5	.0002	0.8	3.8	6.1	13.8	10.3	16.2	-	-	1.8	2.3
	1.0	.0005	0	0.4	2.9	2.1	5.6	6.4	6.5	7.6	0.5	0.6
	3.0	.002	0	2.5	0.4	4.1	3.7	10.0	4.0	22.3	0	0.8
	5.0	.004	0	0	0	0	0	1.0	0	1.0	0	0
Lenzites saepiaria	0.5	.0002	1.5	2.0	5.6	11.3	16.8	23.2	-	-	0.4	0.4
	1.0	.0006	0	0	2.0	2.0	3.2	3.9	7.8	5.8	0.3	0.4
	3.0	.002	0	0.2	0	3.3	1.8	12.1	3.2	17.9	0	0.2
	5.0	.004	0	0	0	0	0	3.0	0	2.3	0	0.7
Lenzites trabea	0.5	.0002	0	1.0	0	1.3	9.2	12.1	-	-	0.2	1.5
	1.0	.0006	0	0.6	0	1.2	0.1	3.2	0.1	5.7	0	1.8
	3.0	.002	0	1.1	0	3.3	0	5.4	0	4.0	0	0.6

1 Beams 4 x 7 mm. tested in static bending under 1.6 kg. load over 10 cm. span.
2 T - treated beams - dipped for 15 seconds.
U - untreated beams.
3 Beams broke under test.
* Beams treated by submersion in warm solution for 1/2 hour.

Gluing Characteristics of Determa

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Satisfactory bonds were obtained with resorcinol-formaldehyde, urea-formaldehyde, melamine-formaldehyde, and casein glues, but not with phenol-formaldehyde. Maximum wood strength followed the same pattern. There is an apparent chemical incompatibility between the phenol-formaldehyde and the wax-like substance in the wood. Removal of the ether-benzene soluble portions of the wax increased the rate of moisture absorption, but the extracted wood was still considerably slower than poplar or gum.

THE PAST 25 YEARS HAVE witnessed an increasing use of many tropical woods for commercial purposes. Part of this increase has been brought about by a reduced supply of high-quality domestic timber for use as veneer, plywood, furniture and other similar products. As yet, however, tropical forests have not made their full impact upon the world's economy, partly because of lack of knowledge of their various properties. As a result, industry has been handicapped in its attempts to make use of the majority of these species.

Most of the past research work in the field of tropical wood utilization has been directed toward studies of the anatomical structure and of the strength properties. Very little work has been accomplished in determining the manufacturing characteristics of the woods.

The Wood Products Laboratory located at the North Carolina State College has for the past several years been investigating the utilization of particular tropical species that have shown superior qualities for a variety of special purposes. Among those chosen was determa *(Ocotea rubra* Mez).

Preliminary work on determa has shown that it is resistant to the marine-borer, possesses a slow rate of moisture absorption, and has a low volumetric shrinkage as compared to native woods of the same density.

Experimental studies at the Wood Products Laboratory on the veneer-cutting characteristics of tropical woods revealed the excellent veneer-cutting properties of determa.

In the process of evaluating determa as a wood for marine use, attempts to glue plywood panels with a phenol-resin were not successful. This raised a question as to the gluing properties of this wood. If satisfactory glue bonds cannot be accomplished with determa, its use will be severely restricted. Accordingly, the objective of this study was to evaluate the gluing properties of determa.

An examination of the chemical composition of determa was performed by Wise and his associates.[2] They stated that the most interesting result of the analysis of determa was the presence of wax in the extractive of the wood. They found that the total content of the wax was over 4 percent. He and his co-workers proceeded to examine the wax and indicated that the compound may be the lactone of a trihydroxy acid (C_{17} H_{30} O_4). However, no compound of this description was found by Wise and his associates in the literature. They made the following statement in regard to the wax-like components of determa:

> "The ether extractives of *Ocotea* are very interesting and deserve a much closer study. The wax-like substance found among the ether extractives may account, in part at least, for the very slow rate of moisture absorption by the heartwood."

Troop and Wangaard[3] presented the results of a preliminary survey of the gluing properties of a group of selected tropical woods. In their results they stated that determa was easy to glue with resorcinol. They obtained an average strength of 1190 psi with 75 percent wood failure by means of the standard block shear test.

Plywood Experiment

Preliminary work on the gluing characteristics of determa consisted of gluing 3-ply panels of 1/16-inch veneer. The glues used were four thermosetting synthetic resins (urea, resorcinol, phenol and melamine) plus casein, soybean, polyvinyl, and animal. The results of this work indicated that there was a difference in joint equality between glues, and in single and double spreading. Therefore a more complete experiment was designed to examine the effect of four main variables on the quality of the glue bond. The variables were:

Glue: a. resorcinol-formaldehyde; b. phenol-formaldehyde; c. melamine-formaldehyde; d. urea-formaldehyde; e. casein.
Assembly time: five levels.
Viscosity: four levels.
Glue spread: a. single; b. double.

This experimental design leads to a total of 200 combinations. A 3-ply panel was constructed for each combination present.

To reduce the effect of inherent variability of the wood, only two veneer bolts were used. All the 1/16-inch face and back veneer came from one bolt, while the 1/8-inch core material was cut from the second bolt. The panels were constructed 8 by 8 inches and were trimmed to 7 by 7 inches. The pressing was performed in a small laboratory hot press. Six shear test specimens were selected at random from each panel. Three of the specimens were tested with the core ply oriented so that the lathe checks were pulled open, and the remaining three oriented to pull the lathe checks close. In all cases, at least one week was allowed before testing was performed.

A discussion of each of the main variables follows. Because the study was to be performed with plywood, was decided to use all of the above formaldehyde-type glues including th

[1] Originally presented at the Fall Meeting, Carolinas-Chesapeake Section, Oct. 31–Nov. 1, 1957, Roanoke, Va. Subsequently part of a MS thesis submitted at North Carolina State College.

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[3] Troop, B. S., and F. F. Wangaard. 1950. The gluing properties of certain tropical American woods. Technical Report 4, Office of Naval Research, Yale Univ., School of Forestry.
[2] Wise, L. D., R. C. Rittenhouse, and C. Garcia. 1952. The chemical composition of tropical woods. FPRS Jour. 6: 237.

phenol-formaldehyde, which had not proved satisfactory in earlier work. In addition, casein was included because of the fairly good results obtained in previous experiments. All the glues used were contributed by various commercial glue companies. Each glue used yielded a separate experiment because of the fact that both assembly time and viscosity were of necessity unique with each individual glue. As a result, each glue was analyzed separately.

Assembly Time. Throughout this study, all reference to assembly time indicates closed assembly time, that is, after the surfaces were spread the panels were assembled immediately. They remained this way until the required assembly time elapsed and were then placed in the hot press. The assembly times used for each glue are listed with the individual glue mixes.

Viscosity: For the purpose of studying the effect of viscosity, four different viscosities were used. In each case, the highest viscosity used represented the mix recommended by the manufacturer. Lower viscosities for the remaining three levels were obtained by increasing the amount of water beyond that recommended. The range of viscosities used depended on the individual glues. In all cases, where the viscosity was decreased the amount of adhesive spread was increased, in order to maintain the same solids content in the glue line.

List of Glues and Glue Variables: The glue mix, viscosity, assembly time and spread for each glue are indicated in Table 1-A.

Spread: The usual practice in the manufacturing of plywood is to spread only one of the two adjacent surfaces with adhesive. Very seldom is the practice of spreading the adhesive on both mating surfaces followed. Both single and double spreading were used in this study, since preliminary work indicated that double spreading produced superior bonds. The amount of adhesive spread was not increased for double spreading; rather the recommended spread was halved and spread on both mating surfaces.

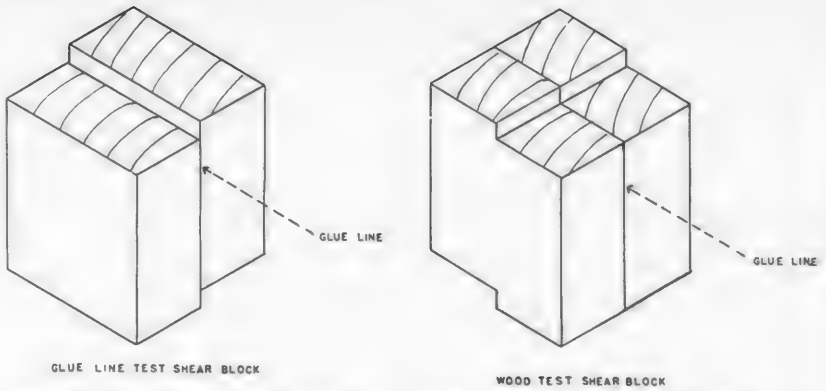

Fig. 1.—A glue line test shear block and a wood test shear block cut from a radial billet.

Results

Because the assembly times and viscosities were different for each glue, the plywood shear test data were analyzed separately for each glue. Table 6 contains the analysis of variance for each glue.

The effects of the variables (spread, assembly time and viscosity) were found to vary with each glue. The glues that were significant for each variable are as follows:

Viscosity: resorcinol-formaldehyde, urea-formaldehyde, melamine-formaldehyde, casein.
Assembly time: urea-formaldehyde, casein.
Spread: phenol-formaldehyde, melamine-formaldehyde.
Checks: all glues.

Assembly Time: For each glue, a range of assembly times was selected that included the recommended assembly time. It was thought that increased assembly time associated with increasing viscosity of the glue mix would aid in the transfer to and the penetration of the unspread surface prior to the application of heat or pressure. This proved to be true with the casein glue. With the exception of casein, however, increased assembly time did not improve the glue bond quality. With resorcinol-formaldehyde, melamine-formaldehyde, and phenol-formaldehyde, it had no effect, while it decreased the quality of the bond with urea-formaldehyde. Tables 1, 2, 3, 4, and 5 show the relationship of assembly time to glue bond quality. Each value listed in the tables is the average psi value of six test specimens from a single panel.

Viscosity: The objective of varying the viscosity was to determine what effect this variable had on the penetration of the several glues into a wood relatively impervious to moisture. It was recognized that extremes of viscosity in either direction would result in poor bonds. Generally, too high a viscosity reduces the mobility to the point where inadequate transfer and penetration occurs. Too low a viscosity

Table 1-A.—LIST OF GLUE VARIABLES

	Resorcinol-formaldehyde	Melamine-formaldehyde	Urea-formaldehyde	Casein	Phenol-formaldehyde
Viscosity A	100 parts resin 117 parts catalyst	100 parts resin 15 parts wheat flour 65 parts water	100 parts resin 60 parts wheat flour 65 parts water 5 parts catalyst	100 parts casein 200 parts water	100 parts resin 30 parts fluefil 50 parts wheat flour 230 parts water
Spread lbs./Msgl.	50	40	50	90	35
Viscosity B	10 parts water	10 parts water	20 parts water	12.5 parts water	70 parts water
Spread lbs./Msgl.	54.3	42.25	54.37	92.81	40
Viscosity C	20 parts water	20 parts water	40 parts water	25 parts water	170 parts water
Spread lbs./Msgl.	58.5	44.45	59.32	96.74	50
Viscosity D	30 parts water	30 parts water	60 parts water	50 parts water	270 parts water
Spread lbs./Msgl.	62.8	46.67	63.66	104.21	60
Assembly times	0, 10, 20, 30, 40 minutes	0.5, 1, 2, 4, 8, hours	0, 15, 20, 30, 40 minutes	0, 10, 15, 20, 30 minutes	0.5, 1, 2, 3, 4, hours
Pressure	100 psi	100 psi	100 psi	100 psi	100 psi
Press temperature	240° F	240° F	240° F	Cold Press	260° F
Time in press	5 minutes	5 minutes	5 minutes	8 hours	6 minutes

Table 1.—RESULTS OF PLYWOOD SHEAR TESTS (psi) WITH UREA–FORMALDEHYDE AS THE ADHESIVE[1, 2]

Viscosity		Assembly time (minutes) 0		15		20		30		40		$\bar{x}$		$\bar{\bar{x}}$
		S	D	S	D	S	D	S	D	S	D	S	D	
A	S	184		160		179		187		154		173		172
	D		183		176		160		189		149		171	
B	S	200		181		196		200		185		192		188
	D		202		189		188		179		162		184	
C	S	184		204		221		189		179		195		195
	D		207		183		193		194		199		195	
D	S	225		201		210		183		201		204		199
	D		189		197		198		188		197		194	
$\bar{x}$		198	195	186	186	201	185	190	188	180	177	191	186	
$\bar{\bar{x}}$			196.5		186		193		189		178.5			188.5

[1]S indicates single spread, D indicates double spread.
[2]The values listed are the average of six test specimens.

Table 2.—RESULTS OF PLYWOOD SHEAR TESTS (psi) WITH CASEIN AS THE ADHESIVE[1, 2]

Viscosity		Assembly time (minutes) 0		10		15		20		30		$\bar{x}$		$\bar{\bar{x}}$
		S	D	S	D	S	D	S	D	S	D	S	D	
A	S	192		204		203		193		209		200		198
	D		186		210		187		193		202		196	
B	S	168		181		174		202		192		183		181
	D		178		176		183		177		180		179	
C	S	163		172		170		181		194		176		185
	D		194		194		202		206		178		194	
D	S	161		168		188		188		173		176		175
	D		158		181		172		166		185		174	
$\bar{x}$		171	179	181	190	184	186	191	186	192	186	184	186	
$\bar{\bar{x}}$			175		185.5		185		188.5		189			185

[1]S indicates single spread, D indicates double spread.
[2]The values listed are the average of six test specimens.

Table 3.—RESULTS OF PLYWOOD SHEAR TESTS (psi) WITH RESORCINOL–FORMALDEHYDE AS THE ADHESIVE[1, 2]

Viscosity		Assembly time (minutes) 0		10		20		30		40		$\bar{x}$		$\bar{\bar{x}}$
		S	D	S	D	S	D	S	D	S	D	S	D	
A	S	248		209		182		212		213		213		211
	D		223		205		188		216		212		209	
B	S	206		197		188		193		198		196		199
	D		212		188		200		193		217		202	
C	S	198		188		215		216		221		207		216
	D		228		225		236		217		219		225	
D	S	190		185		218		212		208		202		209
	D		193		209		207		208		232		210	
$\bar{x}$		210	214	195	207	201	208	208	209	210	220	205	211	
$\bar{\bar{x}}$			212		201		204.5		208.5		215			208

[1]S indicates single spread, D indicates double spread.
[2]The values listed are the average of six test specimens.

results in a glue that is so fluid that a sufficient quantity of glue solids cannot be kept in the glue joint. Between these two extremes there is an optimum viscosity for any combination of glue and wood. It was hoped that the viscosities selected for this study would include optimum.

In the case of resorcinol-formaldehyde and melamine-formaldehyde, this proved to be true (Tables 3 and 4). However, Table 1 shows that decreasing the viscosity of urea-formaldehyde yielded an increase in joint quality in a linear manner. Apparently the range of viscosities used was on the increasing penetration side of the curve, while with casein (Table 2) the range of viscosities was on the decreasing side of the curve. Varying the viscosity had no effect on bonds formed with phenol-formaldehyde. The joints were so poor that no discrimination with regard to viscosity was apparent.

Spread: The third variable, spread, had an effect only with the long assembly time glues, phenol-formaldehyde and melamine-formaldehyde. In both cases, the double-spread bonds were of better quality than single-spread (Tables 4 and 5). The application of the adhesive on both faces accomplishes two things: 1) it eliminates transfer from the actions an adhesive must perform, and 2) the adhesive has a longer time and a better opportunity to penetrate into what is the unspread surface of a single-spread joint.

The improvement of double-spread bonds over single-spread with the long assembly time glues is readily explained. With resorcinol-formaldehyde, casein, and urea-formaldehyde, the adhesive was still in a fluid state when pressure was applied. As a result, penetration was obtained to the same degree whether the adhesive was spread on one or both surfaces. In the case of the long assembly time glues, however, the adhesive had given up most of the solvent before pressure was applied. Obviously the largest portion of the glue, carried by the solvent, penetrated into the spread surface rather than the unspread surface. The only remaining chance for the occurrence of transfer and penetration was during that period, when just prior to setting, the adhesive was in a fluid state. This second fluid state was brought about by the addition of heat to the panel and normally is of a short duration, depending upon the time-temperature cycle. By double spreading, an approximately equal penetration of the solvent and the glue occurred in both surfaces of the joint. As a result, the quality of the bond was improved by double spreading.

The difference in bond quality between glues was not tested statistically. Table 7 reveals the average psi and percent wood failure for each glue. All of the glues were fairly close together with the exception of phenol-formaldehyde, which was approximately 50 psi lower than the others.

A statistically significant difference was found to exist between the strength of plywood shear test specimens that were tested with the lathe checks pulled open and those tested with the checks pulled closed. In all cases, higher values were obtained when the lathe checks were pulled closed. This is in agreement with the findings of Bethel and Huffman[4].

[4] Bethel, J. S., and J. B. Huffman. 19[illegible]. Influence of lathe check orientation on plywood shear test results. Technical Report 1, School of Forestry, North Carolina State College.

Block Shear Experiment

Although the wood failure throughout the plywood experiment was fairly high, with the exception of the phenol-formaldehyde bonds, the psi values were low. For example, resorcinol-formaldehyde showed an average wood failure of 90 percent with an average psi value of only 208. This is considerably below the bond strength of resorcinol-formaldehyde with native woods of the same density. As a result, the block shear experiment was designed to determine if the maximum strength of the wood was being developed.

Two bolts were selected and sawn into radial and tangential boards and marked so as to distinguish between bolts. After the boards were kiln dried to 9 percent moisture content, they were ripped into strips 2½ inches wide and planed on both wide surfaces to a thickness of 1 1/64 inches. The stock was crosscut into 11-inch blocks, which were randomly mixed. They were then separated as to radial and tangential blocks so that radial faces were bonded to radial faces and tangential faces to tangential faces. A tangential and radial billet was bonded with each type of adhesive.

Immediately prior to gluing, the surfaces selected for gluing were jointed.

Throughout this second experiment, the glue mixes and assembly times complied with the manufacturer's instructions. The adhesives used were resorcinol-formaldehyde, urea-formaldehyde, melamine-formaldehyde and phenol-formaldehyde. The pressure was applied with a small press, and clamps were fastened to the billet while pressure was maintained with the press. The clamped pieces, after a sealer was applied to the ends, were immediately placed in an oven with a temperature of 350°. Cure times for each glue had been previously determined to be as follows: resorcinol-formaldehyde = 35 minutes; urea-formaldehyde = 53 minutes; Melamine-formaldehyde = 55 minutes; phenol-formaldehyde = 55 minutes.

Twenty-four hours after the billets were removed from the oven, the clamps were removed and the billets were trimmed to 2 inches by 9 inches. They were allowed to condition for one week before they were tested.

Table 4.—RESULTS OF PLYWOOD SHEAR TESTS (psi) WITH MELAMINE–FORMALDEHYDE AS THE ADHESIVE[1, 2]

Viscosity		Assembly time (hours) ½ S	½ D	1 S	1 D	2 S	2 D	4 S	4 D	8 S	8 D	$\bar{x}$ S	$\bar{x}$ D	$\bar{\bar{x}}$
A	S	205		201		181		193		182		192		192
	D		206		197		188		195		174		192	
B	S	191		198		199		195		208		198		203
	D		203		212		209		199		214		208	
C	S	203		194		205		197		183		196		209
	D		218		233		225		207		226		222	
D	S	168		213		179		217		191		194		197
	D		199		207		208		203		186		200	
$\bar{x}$		192	206	201	212	191	207	201	201	191	200	195	205	
$\bar{\bar{x}}$			199		207.5		199		201		195.5			200

[1]S indicates single spread. D indicates double spread.
[2]The values listed are the average of six test specimens.

Table 5.—RESULTS OF PLYWOOD SHEAR TESTS (psi) WITH PHENOL–FORMALDEHYDE AS THE ADHESIVE[1, 2]

Viscosity		Assembly time (hours) .5 S	.5 D	1 S	1 D	2 S	2 D	3 S	3 D	4 S	4 D	$\bar{x}$ S	$\bar{x}$ D	$\bar{\bar{x}}$
A	S	128		137		140		161		147		143		149
	D		164		163		144		146		157		155	
B	S	143		136		117		117		135		130		141
	D		145		154		149		135		177		152	
C	S	156		152		117		111		101		127		136
	D		175		140		135		177		100		145	
D	S	138		126		146		139		133		136		146
	D		154		178		175		149		129		157	
$\bar{x}$		141	159	137	159	130	131	132	152	129	141	134	152	
$\bar{\bar{x}}$			150		148		140.5		142		135			143

[1]S indicates single spread, D indicates double spread.
[2]The values listed are the average of six text specimens.

Table 7.—COMPARISON OF PLYWOOD SHEAR TEST VALUES AMONG GLUES[1]

	Average psi	Average percent wood failure
Resorcinol-formaldehyde	208	90
Melamine-formaldehyde	200	88
Urea-formaldehyde	189	86
Casein	185	63
Phenol-formaldehyde	143	46

[1]Each figure represent the average value of 120 test specimens from 20 panels.

Table 6.—ANALYSIS OF VARIANCE[1] FOR PLYWOOD SHEAR TESTS

		Urea-formaldehyde			Melamine-formaldehyde			Casein			Resorcinol-formaldehyde			Phenol-formaldehyde		
	DF	S.S.	M.S.	F	S.S.	M.S.	F	S.S.	M.S.	F	S.S.	M.S.	F	S.S.	M.S.	F
Spread	1	1,550	1,550		6,355	6,355	*	158	158		2,768	2,768		20,350	20,350	*
Time	1	6,746	6,746	*	1,383	1,383		3,569	3,569	*	853	853		6,557	6,557	
	3	2,869	956		1,833	611		2,537	846		5,544	1,848		763	254	
Viscosity	1	22,533	22,533	*	1,271	1,271		16,919	16,919	*	10	10		20	20	
	2	2,482	1,241		8,245	4,122	*	964	321		9,339	4,669	*	5,691	1,897	
Checks	1	51,334	51,334	*	38,888	38,888	*	28,275	28,275	*	43,875	43,875	*	35,284	35,284	*
(Spread) (Time)	4	2,071	518		1,866	467		2,525	613		969	242		689	172	
(Spread) (Viscosity)	3	1,121	374		5,280	1,760		5,821	1,940		3,546	1,182		874	291	
(Time) (Viscosity)	12	10,930	911		13,219	1,101		3,954	330		20,981	1,748		34,516	2,876	
(Time) (Checks)	4	942	235		198	50		644	161		6,014	1,503		1,019	273	
(Viscosity) (Checks)	3	3,421	1,170		1,438	479		280	93		1,132	377		1,220	407	
(Spread) (Checks)	1	1,402	1,402		2,700	2,700		13	13		13	13		143	143	
(Spread) (Time) (Viscosity)	12	11,499	958		6,692	558		8,985	749		8,636	720		22,640	1,887	
Residual	31	9,115	294		7,624	246		36,817	1,188		12,104	484		8,557	257	
Triplicates	160	17,352	108		23,465	147		24,800	155		33,217	208		20,571	129	
Total	239	145,367			120,457			136,261			149,001			158,966		

[1]F tests were conducted with the between panel error, "(Spread) (Time) (Viscosity)" except for "checks", which were tested against the within panel error, "Triplicates."
*Significant at 5 percent level.

Table 8.—ANALYSIS OF VARIANCE[1] OF BLOCK SHEAR STRENGTH FOR WOOD VERSUS GLUE TESTING

Sourse	Degrees of freedom	Urea-formaldehyde Sum of squares	Mean squares	F	Melamine-formaldehyde Sum of squares	Mean squares	F	Resorcinol-formaldehyde Sum of squares	Mean squares	F	Phenol-formaldehyde Sum of squares	Mean squares	F
Bolts	1	24,025	24,025		676	676		11,130	11,130		59,536	59,536	
Wood radial vs. Glue radial (Bolts)	1	118,585	118,585	*	154,846	154,846		17,766	17,766		44,105	44,105	
(Wood radial vs. Glue radial)	1	2,592	2,592		57,630	57,630		2,346	2,346		338	338	
Wood tangential vs. Glue tangential (Bolts)	1	85,698	85,698		15	15		1,035	1,035		328,860	328,860	
(Wood tangential vs. Glue tangential)	1	2,664	2,664		21,945	21,945		58,311	58,311		90,312	90,312	
Residual	10	146,523	14,652		860,963	86,096		88,569	8,857		902,867	90,287	
Total	15	380,087			1,096,075			179,157			1,426,018		

[1]F tests were conducted with the (Bolts) (Wood radial vs. Glue radial) interaction for the error term when testing wood radial vs. glue radial. (Bolts) (Wood tangential vs. Glue tangential) interaction was used as the error term when testing (Wood tangential vs. Glue tangential).
*Significant at the 5 percent level.
†Significant at the 6 percent level.

Table 9.—RESULTS OF BLOCK SHEAR TEST SHOWING STRENGTH (psi) AND WOOD FAILURE (%)[1]

Glue type	Bolt I Tangential Wood psi	Glue psi	Glue WF%	Bolt I Radial Wood psi	Glue psi	Glue WF%	Bolt II Tangential Wood psi	Glue psi	Glue WF%	Bolt II Radial Wood psi	Glue psi	Glue WF%	Glue x̄
Resorcinol-formaldehyde	1254	1051	95	1106	1198	90	1039	1258	100	1016	1038	80	
	1279	1186	100	1190	1218	90	1183	1351	100	970	1205	95	118
Melamine-formaldehyde	1258	1092	100	920	880	80	1075	779	30	1123	1589	90	
	1416	1378	100	765	990	90	896	1407	85	641	1076	30	114
Urea-formaldehyde	1351	1075	100	870	981	100	1245	1020	90	668	1015	100	
	1182	971	100	952	1106	100	1096	980	80	891	953	100	101
Phenol-formaldehyde	1448	922	100	1082	992	40	1213	956	100	1067	1095	80	
	1588	880	70	1093	912	60	983	852	50	1063	712	40	91

[1]Each value is the test result from one specimen.

plied at right angles to the glue line. As a result of this, the wood, rather than the glue line, was tested for shear (see Fig. 1). The remaining two specimens were tested in shear along the glue line in the conventional manner.

To compare the wood test to the glue test, the comparison must be made between glue tests from the radial block and the wood test from the tangential block. In addition, the tangential glue tests must be compared to the wood tests from the radial block. The reason for this lies in the fact that, when the wood test specimen from the tangential billet is rotated 90 degrees, radial wood is tested. Also if the wood test specimen of the radial billet is turned 90 degrees, tangential wood is tested. Therefore, the wood test specimens and the comparative glue test

A total of four block shear specimens were cut from each billet. Since two billets, one tangential and one radial, were prepared for each glue, a total of eight block shear specimens were obtained. To determine if the glue bonds were developing the maximum strength of the wood, two of the four block shear test specimens from one billet were rotated 90 degrees so that the shearing force was ap-

Results: An analysis of variance for each glue was performed to determine if any real difference existed between the glue tests and the wood test (Table 8). Table 9 presents the four glues and the results of both the wood and glue tests.

Table 10.—STRENGTH OF PHENOL–FORMALDEHYDE AND MELAMINE–FORMALDEHYDE BONDS ON EXTRACTED AND UNEXTRACTED DETERMA[1]

	Melamine-formaldehyde psi	Melamine-formaldehyde W.F.	Phenol-formaldehyde psi	Phenol-formaldehyde W.F.
Unextracted wood	189	85%	148	69%
Extracted wood	181	96%	195	88%

[1]Each value is the average of 12 shear specimens from two panels.

A significant difference between the wood and glue tests was found for urea-formaldehyde radial blocks and for phenol-formaldehyde radial blocks. In the case of the urea-formaldehyde, the glue test was higher than the wood, which indicates that the maximum strength of the wood was developed. However, the phenol-formaldehyde radial glue test was lower than the radial wood test. With the phenol-formaldehyde, the evidence indicates that the maximum strength of the wood was not developed. Table 9 indicates that the glue tests were consistently lower than the wood test with the phenol-formaldehyde. With this exception, the data indicated there was no difference between the wood and glue test results. Apparently the strength of the wood was developed with all glues but phenol-formaldehyde.

The close agreement of the block shear test results, when resorcinol-formaldehyde is used, with the results of Troop and Wangaard[3] should be noted.

Rate of Moisture Absorption

Because it was realized that the rate of moisture absorption by a species of wood would affect the gluing characteristics, a third experiment was designed. The objective of this experiment was to compare the rate of moisture absorption of determa with that of poplar *(Liriodendron tulipifera* L.) and gum *(Nyssa sylvatica* L.) It was also decided to compare the rate of moisture absorption of determa after a portion of the wax-like components had been removed. Wise[2] indicated that the slow rate of moisture absorption by determa may be due to the presence of these waxy compounds.

Three veneer samples, 1/16 inch thick and 2 inches square, of each species were placed in an oven at a temperature of 215° F for three days. At this time the weight of the samples remained constant. The samples were then placed in a room set for an equilibrium moisture content of 10 percent. For the first hour, the samples were weighted at 5-minute intervals. The time interval was lengthened to 10 minutes for the next half-hour, and then to 30 minutes for the remainder. In addition to this, three samples of the three species were placed in a desiccator and separated with glass rods. A solution of ether and benzene mixed in equal proportions was placed in the desiccator. Heat was applied so that the solution evaporated and passed over the wood into a condenser, where it was condensed and returned to the desiccator. This process was allowed

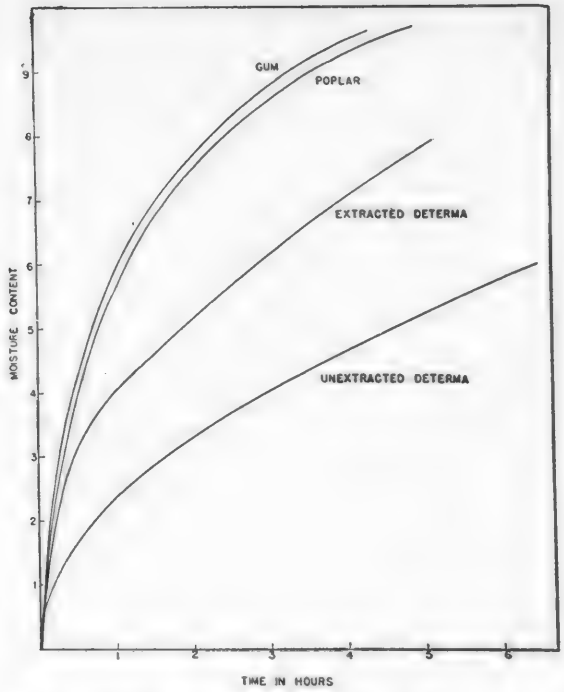

Fig. 2.—Moisture absorption curves for poplar, gum, and determa.

continue for 12 hours. The solution of ether and benzene was changed every four hours. As a result of this process, the bulk of the ether-benzene soluble portion of the waxy components present in determa was removed. The extracted samples were also oven dried and subjected to the same procedure as the unextracted samples. The poplar and gum samples were also subjected to the extraction process as controls. A direct comparison was made between the rate of moisture absorption for extracted and unextracted samples.

Results: Fig. 2 illustrates the rate of moisture absorption of determa as compared to poplar and gum. Unextracted determa had a considerably slower rate of moisture absorption than poplar or gum. After one hour, the moisture content of determa was 2.35 percent. However, the extracted samples of determa absorbed moisture at a faster rate than the unextracted. At the end of one hour, the moisture content of the extracted samples of determa was about 4 percent. Although this figure is higher than that of the unextracted determa, it remains lower than those of poplar and gum. The samples of poplar and gum that were subjected to the extraction process were no different from the original samples with respect to rate of moisture absorption.

Gluing of Extracted Wood

Because of the poor performance of phenol-formaldehyde resin, an investigation of the relationship that might exist between phenol-formaldehyde and determa was warranted. Accordingly, a fourth experiment was conducted to determine if any relationship existed between the phenol-formaldehyde and the waxy component of determa.

Two 6 inch by 6 inch 3-ply panels of extracted wood were constructed with phenol-formaldehyde, and two panels of unextracted wood were also made. The extraction of the ether-benzene soluble portions of the wax was performed on 1/16 inch veneer by the same procedure as outlined in the rate of moisture absorption experiment. In addition, the same number of panels were made with melamine-formaldehyde. The veneer was cut from a different bolt than the veneer used in the preceding plywood experiment. A comparison was made between the glue bond quality of the extracted and unextracted wood.

The removal of a large part of the ether-benzene soluble portion of the wax present in determa caused a considerable increase in glue bond quality when the glue used was phenol-formaldehyde. Table 10 presents the average psi and wood failure of each panel. The removal of the wax caused no difference in the bond quality when melamine-formaldehyde was the adhesive. The improvement of the bond with phenol-formaldehyde, when the wax was removed, indicates some sort of chemical incompatibility between the wax and phenol-formaldehyde. This would explain the poor showing of phenol-formaldehyde with determa. The incompatibility may be due to a difference in polarity, which would result in the failure of the phenol-formaldehyde to wet the wood, or to secure adequate penetration. The failure of either of these to occur would bring about a joint of poor quality.

Conclusions

1. With the exception of phenol-formaldehyde, satisfactory bonds can be obtained with all glues used in this study.
2. The gluing of determa with resorcinol-formaldehyde presented no special problem and can, in agreement with Troop and Wangaard, be classified as an easy wood to glue with resorcinol-formaldehyde.
3. With casein, the best bonds are formed with longer assembly times and the recommended viscosity or mix.
4. Decreasing assembly time and viscosity yield a superior joint when determa is glued with urea-formaldehyde.
5. All glues used in this study, with the exception of phenol-formaldehyde, develop the maximum strength of the wood.
6. The wax-like substance present in determa is largely responsible for the very slow rate of moisture absorption exhibited by this wood. This supports the theory advanced by Wise and his coworkers that the wax may account for the slow rate of moisture absorption.
7. A chemical incompatibility apparently exists between phenol-formaldehyde and the wax-like substance in determa. With the wax removed, a satisfactory joint can be obtained with phenol-formaldehyde.
8. With the exception of casein, increasing the assembly time did not improve the quality of the bond.
9. Decreasing the viscosity from that of the recommended mix improved the quality of the bond with urea-formaldehyde and melamine-formaldehyde.

HANDLING GREEN LUMBER IN A SMALL MILL BY

Automated Sorting and Stacking[1]

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A case history of the achievement of a high degree of semi-automation in a small sawmill and remanufacturing operation. Investment returns have proved to be worth while.

SAWMILLS AND REMANUFACTURING plants have to review constantly their handling and processing costs. This was particularly true at the WSM Division of the Powell River Lumber Company, Ltd., in New Westminister, B. C. Here was an operation which had a fairly modern sawmill, a bank of dry kilns (eight double, five single), a modern planer mill, a cut up plant, and a new moulding plant just under way in 1956.

For some period of time, the mill had been cutting three species; Douglas Fir, Hemlock and Alaska Cypress (Yellow Cedar). The operation also purchased and remanufactured Douglas Fir and Hemlock and dried and shipped industrial spruce clears. This mill, together with its sister plant, the BCM Division, cutting Western Red Cedar, served rail and export markets all over the world.

The annual cut of the WSM mill was about 30,000,000 FBM, and custom purchased and processed lumber added another 6,000,000 FBM. The distribution of this volume varied among the four species, and was dependent on supply, season, and markets. The mill manufactured and sold everything from 26 foot timbers to 12-inch toy block stock.

The mill layout resembles the rest of the sawmills and remanufacturing operations in the industry today. It had grown in all directions; some machines and operations were pointed the wrong way. Some of the equipment was old, and some equipment and operations were quite new.

As if the species, the markets, and the layout were not enough problems in themselves, the mills had recently changed ownership and management. With more critical times at hand, particularly cost margins, coupled with rising costs of improvements, new capital expenditures were being given a real good look.

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The Problem

The mill had no scarcity of problems. The industrial engineer, upon reporting to the manager, had been instructed that there were problems fifty feet from any door. Cost, however, was the basic problem. Log cost was something that could only be lived with or argued about, but generally to little or no avail. Other cost areas such as maintenance, supplies, and the like offered some potential for savings, but labour costs appeared to offer the most potential for improvement.

After reviewing the process from the drag saw to the loading areas, we generally agreed that the most critical area was the yard handling, sorting, and kiln packaging of green lumber. Drying requirements were about 18,000,000 to 20,000,000 FBM per year, which was the approximate capacity of the kilns at that time, including some air seasoning.

The sawmill had a short green chain. The mill attempted to do some kiln packaging at the chain by hand, and had done so for years. In addition there was a separate operation which is referred to as the stripping operation, where seven men per shift handled the custom or purchased stock, all of the clear, tight knotted, and shop requirements. This operation worked two shifts every day, averaging about 40,000 FBM per shift, which occasionally got behind, and was supplemented by hand sorting and piling in the yard, say two men per day, or had to work the occasional weekend.

It was the practice to kiln pile strip narrow clears and special items at the mill green chain. There was a total of 9 to 12 men on the green chain on a normal crew, 7 to 10 which sorted and piled timbers or commons, and 2 sorted and stripped specials and narrow clears.

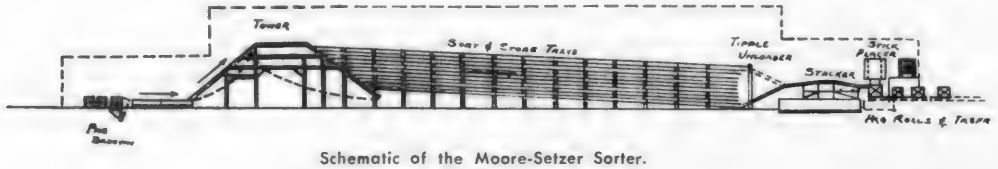
The green chain crew would vary because of species, the log cut ranging from 55,000 to 85,000 log scale depending on species, or orders, or both. Here were about 18 men involved in sorting, handling and kiln packaging of only about 90,000 to 95,000 FBM per day.

This was a serious problem; a real high cost operation. How much of this cost was recovered by "specials" was debatable.

The Considerations and Requirements

There were some complicating factors as to location and integration of a lumber sorter and/or stacker. One bank of older kilns (9 tracks) were pointed toward the cut up plant, where in the wooden box days, box shook just poured out. Now it was a long haul to the planer mill. The newer kilns (3 double kilns) were pointed at the planer but were a longer haul from the sawmill. The mill could not install any lengthy extension to the green chain before running into a property line. If this were done, the planer mill would be cut off from the scow loading dock. The wide range of sizes, grades and lengths required a con-

[1] Presented at the FPRS National Meeting at San Francisco June 28-July 3, 1959. Received by F.P.J. June, 1959.



Schematic of the Moore-Setzer Sorter.

AERIAL VIEW of WSM Division of Powell River Lumber Co. Ltd., where Moore–Seltzer sorter is located (at left side just below center).

CLOSE UP of building where Moore–Seltzer sorter is located.

INPUT END of the sorter showing the inclined transfer to the tower.

LOOKING UP THE SORTING TRAYS, showing the tiple unloader to the stacker in foreground.

OUTPUT END of the operation, showing chain arm stacker, sticker placer and package hoist, outfeed rolls and package transfer.

bined total of about 72 different kinds of loads from the mill green chain and the stripping chains. (See Fig. 1).

Lengthy discussions were held by supervision, the mill management and staff. For a long time nothing came of the discussions. Short discussions were held with top management. Something came of these discussions. The mill had to set up the desirable characteristics and quickly. These were:

Type—The sorting and stacking should be combined.

Volume—90,000 to 95,000 FBM per day on a 5 day week.

Range of Sizes—1 x 3, to 2 & 3 x 12. Some 4 x 6.

Manpower—A minimum, but this would also have to be considered along with capital cost. The mill hoped for 6 men in 8 hours, or some such arrangement, assuming that whatever was done should be at least twice as good.

Space—Wide enough to handle 26′ lumber if necessary. Long enough to give the sorts necessary.

Location—Should be located so as to handle the sawmill cut for the kilns, to permit handling and input of custom or purchased lumber, and not to make the material flow problem any worse.

Capital Cost—Could range anywhere from $50,000 to $150,000 if the savings would justify the expenditure. Mill management and top management both recognized that it wouldn't be cheap.

Horsepower—Little was known about sorter-stackers, but this would only be a factor for an extensive or elaborate machinery layout. It takes horsepower to manufacture lumber, but not necessarily to sort or handle lumber.

Maintenance—The mill had more than enough millwrights, electricians, etc., and did not want to add to this crew, but would if the results were forthcoming.

Ease of Operation—Sorting and kiln piling are simple operations. Any new installation should be kept simple, because only simple decisions needed be made and mechanical stacking was widely operative.

Inventory—The mill had a choice. It could run from current production at a low footage rate and devise means to introduce custom lumber, or run from inventory in batches, which would require an increase. There were already some inventory problems, due to kiln loading, and variable percentages developing from current cutting, as well as the irregularity of the custom lumber program.

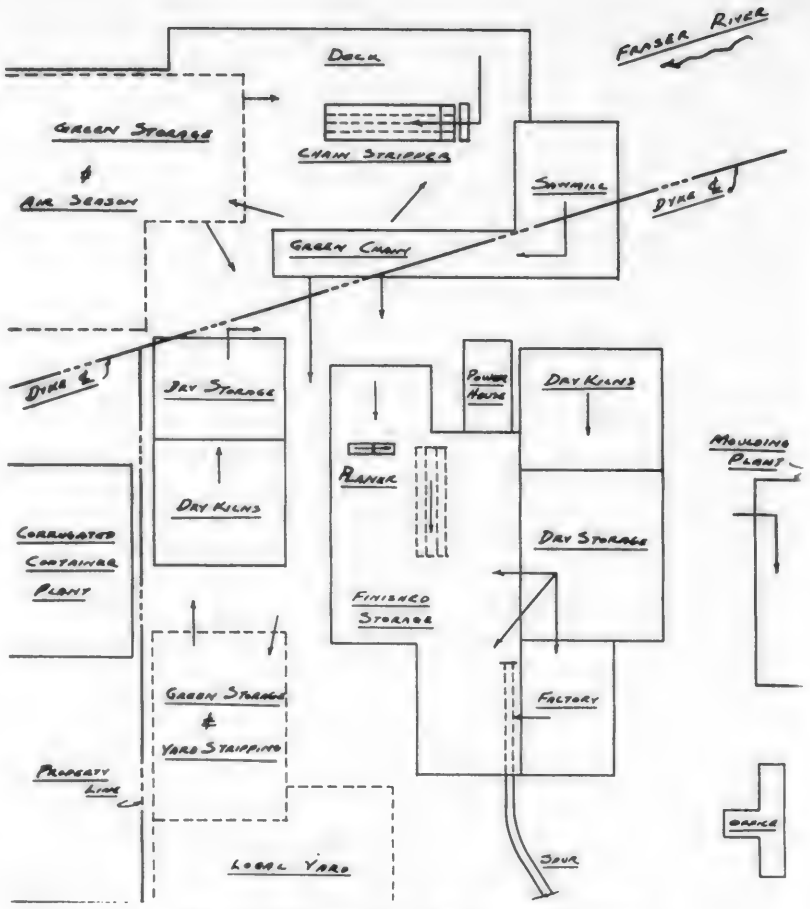


Fig. 1.—Plant layout and flow—before automation.

Obsolescence—There had been a rash of sorting and stacking installations throughout North America in recent years. A good sorter-stacker installation should be a competitive operation for at least ten years. The matter of obsolescence meant the operation should perform for at least 10 years. If not, the operation would have to be adaptable to other processing ahead or before, and still be useful if a change in processing occurred within a short time, say within two or three years.

Alternate Selections

All members of the management group looked for alternates for consideration. There were quite a few sorter operations, some sorter-stacker operations and many stacker operations.

The problem began to resolve itself when it was realized from discussions that concessions would have to be made, particularly in view of local limitations. There were fixe variables; width, grade, length, thickness and species. After taking a long look at these, the conclusion was reached that we should begin to make some substantial concessions.

There was not an ideal solution to all of the foregoing. The "ifs" began to enter the picture. If certain sizes could be combined, if certain sizes could be ignored, if some could be hand piled as before, if the premise could be accepted that 90% solution would be acceptable, if the maximum cost reduction target were foregone, if inventory increases were permissible, then what would happen? Should local limitations require modifications to location or design of an existing sorter-stacker previously considered, could any be made, and would these help any with regard to the problem?

A look was taken again at sorters. Another at stackers. A further look was taken at the problem at home. If one wanted to figure the combinations they could amount to 1134! "Length" was the worst offender. "Species" was the least. "Grade" was no real problem as this involved three separation "Thickness" had to be solved by d kiln lots, and could be since there we 8 doubles and 5 singles. "Width could or could not be grouped, accor ing to end product. Another look w taken at the plant yard and reman facture layout, and at the method handling lumber in and out of sorter-stacker.

One by one, the various sorte

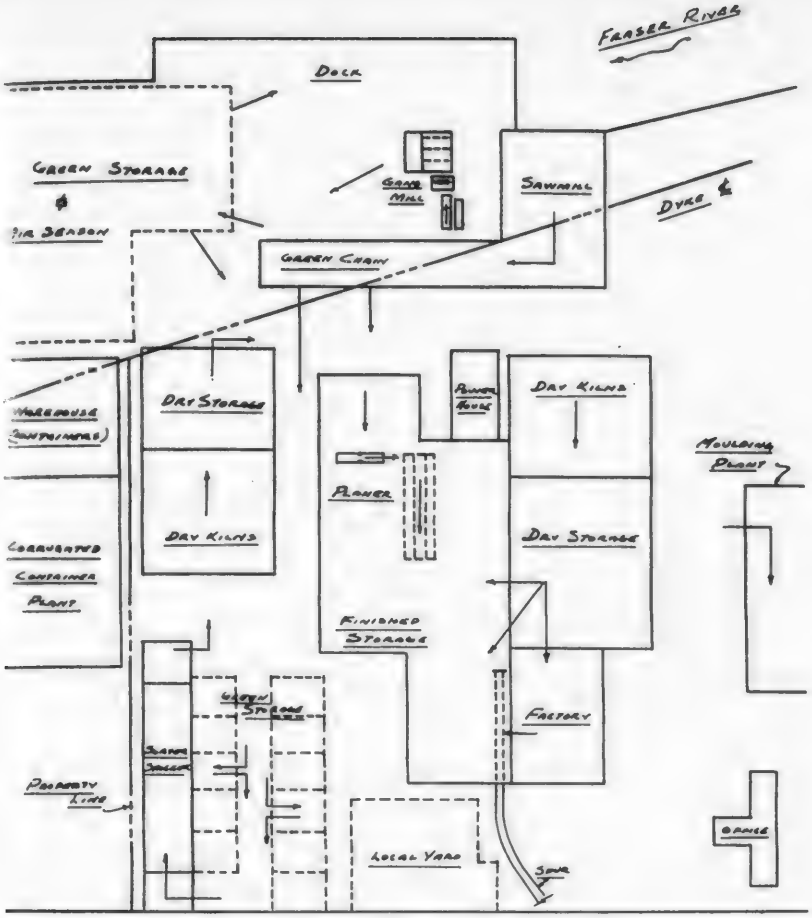


Fig. 2.—Plant layout and flow—after automation.

stackers fell out of the picture. Some didn't fit at all, some required too much money, or too much room. A long sorter would cut off the mill from the shipping area. The sawmill green chain was not high enough, or could not be extended over a valley. Species requirements, outside purchases and grade development indicated that the sorter-stacker should be away from the sawmill green chain. It then became apparent that there would be an inventory problem either ahead or behind a sorter-stacker, and also a change in thinking as to who would supervise or direct the operation, and why.

The Selection

We finally chose the Moore–Setzer sorter, and the particular one which most of the management group visited was located in northern California. This was a roller tray sorting system, a king size gravity filing system; combined with a tipple unloading and stacking operation.

Fitting the same, or a similar operation into local operational requirements presented some problems. Certain modifications would be necessary, but these could be made. A plan was that the operation was to be located away from the sawmill green chain. The second departure was the arrangement of sorts by lengths, and roll (or trays) spacings. The third departure was the method of feeding the machine as the original sorter-stacker was mill served, excepting certain sort outs. The new application would have to be served by primary rough sorts, package fed by carrier or fork lift in solid loads. The fourth departure, but not necessarily important, except in capital cost differentials, is that the operation needed to be housed, as there is a substantial difference in annual rainfall between northern California and the lower mainland of British Columbia.

The Selling Job

Regardless of the enthusiasm, merit, novelty, and all else, with respect to any new project or installation, all that management wants to know seems to be: 1) How much? 2) How soon is the investment returned? and, 3) Why wasn't this done earlier? Answers to 1 and 2 are generally quite simple; 3 poses some problems. The problem had been one of those which had been worked out. The first departure was lived with for a long time, and because the excess cost had been sort of lumped in as part of the handling, packaging, and drying costs, it seemed to have taken care of by the "drying differential." Serious and concentrated attention and consideration just had not been given it.

Cost estimates were prepared, the location selected, and the case was presented to management. After some discussion the project was approved; 1) because the returns looked attractive, 2) something needed to be done about the excess manpower used, and 3) 1955–56 wasn't too bad a year for most sawmills in North America.

The Installation and Start-up Problems

The installation was started in the summer of 1957. It is probably an understatement to say that there were some problems. The company supplying the prefabricated equipment was doing it for the first time, and the mill management group had all climbed into the same selling boat. In spite of the fact that there were too many "chiefs" and not enough "indians," the operation started up the day after Labour Day.

The operation is housed in a building 40 x 300 feet. It is package fed by carrier or fork lift from inventory and from the current cut. Solid packages are broken down to trays holding slightly more than a kiln package of 1 inch lumber. It is semi-automatic. The stacker operation makes up packages as the trays are filled, leaving the balance to start the next package. Total horsepower requirements for the operation amounts to about 100, including lighting. Stock is taken away by carrier or fork lift, depending on the kilns being served. There is practically no maintenance cost.

After the shakedown period of two or three weeks, when most sizes were attempted, the operation began to perform. To the best of our knowledge there were no operations like it in the Pacific Northwest. All of the suggested "attachments" were not introduced immediately, nor were all of the dry kiln requirements put into the operation at once. However, within six weeks time, the operation was handling the volume required, and it was off and running. A pocket-fed stick placer was added later.

Operation Today

The operation is now supervised by the dry kiln foreman, averages about 90,000 FBM per shift, stickered and packaged with five men, and depending on kiln scheduling and species, will take care of all dry kiln requirements in from 3½ to 5 days a week.

Perhaps an indication of what the sorter-stacker does can best be shown by the following table, rounded off to the closest 5,000 FBM for convenience. Keep in mind that this is largely a machine controlled operation and that sometimes the feed end governs, and sometimes the stacker end governs, due to lug spacing, chain speed, stacker speed and height, and number of tiers (lumber thickness and stickers).

CAPACITY IN FBM

	8 Hours		
	2, 3 & 4	6–8	10–12
1"	55,000	95,000	95,000
5/4"	70,000	115,000	115,000
6/4"	90,000	125,000	125,000
2"	100,000	130,000	130,000

These are obtained by making a rough sort at the green chain, say for 1-inch Clears to 1 x 6 & 8, all lengths and 1 x 10 & 12, all lengths.

Then, at the sorter-stacker, the lengths and widths can be broken down again to widths, and a compromise on lengths. (See diagram for tray spacing or lengths handled). The kiln foreman may change some assignments.

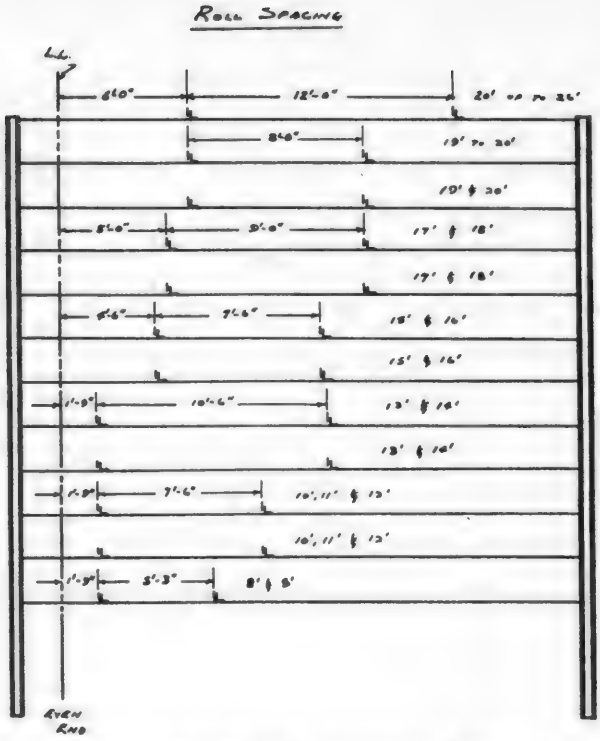
The sorter-stacker runs "batches" of about 100M in 1 inch, to 140M in 2 inch at a time, or about 5 percent over a double kiln charge. This footage requires about a bay and a half to two bays (See Fig. 2). The odds and ends left in the tray system from each run are run out, solid piled back to inventory to be run with the next sorter run, or stickered, and the next run in that thickness and species cut short. Some clear stock is stickered and dried and segregated at the planer mill in 1x2 and 3, or combination of 1x3 and 4 as suits the production requirements of remanufacturing operations. Gang sawn stock improves the performances indicated above.

Limitations

The sorter-stacker has 12 trays and a reject. A better sorter might have 13 trays, and a "reject." "Reject" could be another tray, or simply a pile of boards to be cleaned up. The sorter-stacker can be improved, as is being done at this writing. This sorter, as built, will not handle 4" material but this is not critical. Neither does it handle 2" x 2" stock due to roll size and roll spacing, but again these sizes are not high volume items.

Direct Savings

As previously stated, the mill had been using a basic crew of 18 men to do the total job of sorting and stacking. Whether or not these were full-time employees on sorting and stacking, or on relieving, or sweeping, the labour dollars were there. The same task is now being done by five men today. The sorter-stacker still has unused capacity, varying anywhere up to a day and a half per week. The crew then moves to the shipping yard, or sweeps. In any event, these numbers have at least disappeared from the time clocks. The green chain crew has been cut an average of two men on both shifts, and no "stickering" has been done in the yard, except on 4-inch clears or decking, which is a very small percentage of the total volume.



Schematic Roll Spacing, Moore-Setzer Sorter.

One of the difficult things to assess, and quite a substantial saving in itself, was the "forcing" of all concerned to consider seriously the dimensions of kiln loads. Either due to custom or habit, past practice on 6-inch was to place six pieces per tier, and on 8-inch was five pieces per tier. Introducing the chain arm stacker required mechanical stops, and 50½" face to face worked out best. In theory, this would calculate to be 14 percent on 6-inch and 20 percent on 8-inch, 25 percent on 10-inch and no percent on 12-inch. This is noted here only.

Variations in sawing, warped tension stock, and the behaviour characteristics of groups of boards cut these percentages down on an occurrence basis, which can be readily noted by looking at the "chimneys," just inside the left hand boards in the kiln package. The mill cut longer kiln sticks, enlarged the carrier straddle openings, and widened the kiln doors. It is estimated that a good 10 percent or about 200,000 FBM more footage in and out of the dry kilns per month, on width alone, more uniform heighths, with no tag end, probably added another 5 percent.

Indirect Savings

With an improved control of both the size and length of kiln packages, better drying is achieved. Tag end packages into the kilns do not exist where openings used to vary anywhere from 2 to 4 feet between odd length ends on kiln cars. Circulation would follow the lines of least resistance and a poorer job of drying had been done. With less of this situation to contend with, more uniform drying had to result, together with some slight increase in kiln utilization. This of course, with no "before" and "after" controlled tests, the mill accepts at face (or conversation) value from the planer mill and other remanufacturing operations, but it is there.

Results

The mill returns its investment in a little over two years, over the previous operational costs, even after considering the cost of carrying some additional inventory and depreciation.

The sawmill cuts as before for the best in the log, and at as high a production rate as is practicable, and the sorter-stacker runs to suit the dry kiln and planer mill. This has simplified the job of the production control man in normal markets, considering the cu-

tom and purchased program. All concerned are satisfied with the operation and the results to date, chiefly because of the improvement over the old method, and the labour cost reduction.

The Future

There are many possibilities to the operation. It can and has been used in the off hours for special sorting where economically justified. It has been used to help the other division on another species. Consideration is being given to processing some commons over the operation. Other operations such as yard trimming, green planing, or resawing can be integrated into the operation.

Plans are now being implemented to reduce the crew by one man with a nominal capital expenditure for electrical controls, and a slight change in primary sorting at the input end.

Studies are underway to determine the extent and application in the BCM division, to apply the same operation, or some modified version, to supplement or shorten two green chains. There the daily log cut is about double, as are the dry kiln requirements.

Conclusions

Complete automation was not obtained. A very high degree of semi-automation was achieved. The mill has introduced a new method of sorting and stacking to the Pacific Northwest. Another operation is introducing the same basic concept and slightly larger equipment into its rebuilding program in Washington and it is pleasing to note that it again is being applied in a medium-size saw milling and remanufacturing operation.

New applications might consider two such units, or one larger unit. The sorter-stacker can be fitted into a mill, with a bypass or a pull out, or operated independently. The merits of eitheir application would have to be determined by the requirements. Some operations may not have the wide cost reduction margin to improve. The mill is still considering improvements to this sorter-stacker, both manpower wise, and usage wise, because there are newer and better ways being devised every day.

Wood Waste in Composts[1, 2]

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A quarter ton of sawdust for every thousand feet of lumber sawed. Can some of this waste material be salvaged to improve our soils? Experiments say yes—but with qualifications.

ACCORDING TO CORDER (3)[4] FOR each thousand board feet of lumber sawed in sawmills about a quarter ton (dry weight) of sawdust is produced. This amounted to over 2 million dry tons in Oregon alone in 1955, and it was estimated that about a third of this sawdust was not used. These figures are indicative of the relatively large amounts of woodwastes of various kinds that are potentially available for agricultural uses, such as soil improvement.

Earlier work at this Station with lignin of various types (4) indicated that wood-hydrolysis lignin had some potentialities in soil improvement. This would consist chiefly in changing the physical character of the soil, such as alterations of soil structure, ease of water penetration, and water and nutrient holding capacity. The effects of such changes would be more amply demonstrated in field tests rather than with greenhouse pot cultures. Since sawdust and other forms of wood waste are ordinarily far more abundant and readily available than lignin, it seemed advisable to turn to these for experimentation.

This report is the final one in a series of papers (2,7,9) on the composting of sawdust and shavings and studies of the effects on plant growth of the resulting composts as well as other wood wastes. One phase of this work (6) was on a field plot basis. This dealt with a comparison of fresh and rotted sawdust with farm manure as aids to growth of field corn. Yields were best with rotted sawdust, poorest with fresh sawdust, while the plots with manure and the control plots were intermediate in their yields. To avoid the adverse effects of fresh sawdust and to hasten the decomposition of wood waste, compost tests were begun.

Methods of Composting

The various methods used for composting these wood wastes on a relatively large scale under outdoor conditions were as follows: (a) wooden bins, contents well aerated, no water added other than natural preciptation; (b) piles of compost, with added water; (c) pits in ground, no added water, but contents partly flooded at certain times of year; (d) wooden bins without aeration, but with added water. Many of these were filled with mixtures of sawdust with manure or other materials added to speed up or aid decomposition.

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[2] Presented at Session XIII, Chemical Utilization, of the Twelfth National Meeting of the F.P.R.S., June 22–28, 1958, in Madison, Wisconsin.

[3] This report is based partly upon portions of a thesis presented by the junior author in partial fulfillment of the requirements for the degree of M.S. at the University of New Hampshire.

[4] Numbers in parentheses refer to the Literature Cited at the end of the paper.

Fig. 1.—Outdoor wooden bins used for storing and processing sawdust composts.

Fig. 2.—Cultures of rye plants growing in wooden boxes outdoors tests on wood waste composts.

Other miscellaneous treatments on a smaller scale, mostly indoors, consisted of: (e) acid hydrolysis of sawdust, with and without steam treatment; (f) sawdust plus fish waste; (g) sawdust plus green vegetation, finely pulped; (h) sawdust plus manure with steam treatment before and after mixing; (i) sawdust plus commercial fertilizer and lime. Most of these treatments were done with relatively small amounts, in large glass jars or other similar sized containers. The methods of treating and mixing these materials, the kinds of containers, as well as results with plants grown in them have been described in previous publications (2,7,9).

Extensive tests also were made on waste bark (5) at this Station, both in field plot trials and in greenhouse cultures. This material was found to have some promising potentialities when used in various ways. It was particularly advantageous as a mulch for roses and for other perennials. In many instances it could substitute for peat moss in horticultural practices.

Of all the composting methods described in these papers, the best one was that of (d) in which mixtures of sawdust with manure or other aids to composting were placed in wooden bins of about one cubic yard capacity. The contents were kept wet as needed to aid the composting process. They have been described previously (2) and the type of bin used is shown in Fig. 1.

The second best method was that of (c) in which the materials were placed in outdoor pits dug in the ground. A description of these pits and discussion of some of their disadvantages, as well as some of the results with growing various crops in the partially composted contents of these pits have been published (2). However, since this publication, further studies on plant growth have been made with these materials, as well as with those from the wooden bins, mentioned above. Here are presented these additional results, correlated with the previous data. In addition, plant growth results with some other miscellaneous mixtures are given.

Experimental

1. Outdoor cultures with compost mixtures in wooden boxes

Here will be considered growth studies with the materials from the pit composts in comparison to mixtures freshly prepared. There were nine pits dug three feet into the ground and the upper walls were of brick one foot above the ground. Each was four feet wide by six feet long. Mixtures of birch shavings, on a volume basis, were placed in them as follows:

Pit 1. Pure white birch shavings; Pit 2. ¼ cow manure, ¾ shavings; Pit 3. ¼ hen manure, ¾ shavings; Pit 4. ⅓ shavings, ⅓ fresh silage, ⅓ mixture of cow, hen,[5] horse manure; Pit 5. ¼ horse manure, ¾ shavings; Pit 6. ½ shavings, ½ silage; Pit 7. 5% 5–10–10 fertilizer, 5% ground limestone (30% $CaCO_3$), 90% shavings; Pit 8. 5% limestone, 25% cow manure, 70% shavings; Pit 9. 5% limestone, 25% hen manure, 70% shavings.

A year later, samples of these were taken for testing with plant growth in pot cultures in the greenhouse. The methods of growing these plants and the yield results from them already have been described (2). For reasons also discussed there, one year later, or two years after the start of these composts, outdoor cultures with these and other materials were started in wooden boxes, also described in this publication. Each box was 6 feet long, 2 feet wide, and 1½ feet deep. There were 20 of these long boxes and each was partitioned in the middle so that there were 40 plant growth compartments each 3 feet long. All future mention of the word "box" will refer to those individual compartments. Holes were made in the bottoms and the boxes were placed on a bed of gravel to aid drainage.

The mixtures used in these boxes were as follows: 1. 25% rotted sawdust, 75% soil; 2. Krilium and soil (recommended mixture); 3. 2.5% sewage, 22.5% fresh sawdust, 75% soil; 4. 10% sewage, 90% fresh sawdust; 5. 2.5% sewage, 97.5% soil; 6. 2.5% hen manure, 22.5% fresh sawdust, 75% soil; 7. 2.5% hen manure, 97.5% soil; 8. 6.25% sewage, 18.75% fresh sawdust, 75% soil; 9. 25% sewage, 75% fresh sawdust; 10. Control (soil only); 11. 25% compost Pit 1, 75% soil; 12. 25% compost Pit 2, 75% soil; 13. 25% compost Pit 3, 75% soil; 14. 25% compost Pit 4, 75% soil; 15. 25% compost Pit 5, 75% soil; 16. 25% compost Pit 6, 75% soil; 17. 25% compost Pit 7, 75% soil; 18. 25% compost Pit 8, 75% soil; 19. 25% compost Pit 9, 75% soil; 20. Control (soil only).

Each of the above mixtures was duplicated once to fill the 40 boxes, giving four replications for the controls.

Rutabaga, rape, peas and onions were grown in these boxes. Later, winter rye and table beets, Detroit Dark Red variety, were grown. Because the tops and roots of the beets were harvested separately, there were available seven different sets of data for the assessment of the effects of these mixtures on plant growth.

Between harvesting of each crop and the planting of the next one, the compost or other materials in each box were thoroughly re-mixed. At this time a soil test for major plant nutrients was made. Before planting the next crop, nutrients of fertilizer grade were added to correct for any deficiencies appearing. This was true of all other plant cultures to be described here where more than one crop was grown in a given series.

[5] This means poultry manure as used here and subsequently.

Because of their bulk, the tabular data for yields from these cultures will not be presented here. The three sets of yield figures for these crops were combined with those for the four crops previously published, to show the relative positions of the mixtures based on crop yields. These are given in Table 1. Based on this they are listed in that same order in Table 2, for ease in correlating components of mixtures with the numbers.

Some comments and observations now will be given on the general character and growth of the two crops the data of which has been incorporated in this general summary. The rye was harvested at the heading-out stage. The seven rows in each box were harvested separately, making 14 samples per treatment. In those in which it grew well, the growth and vigor was very rank, and much of the rye reached a height of four to five feet. Fig. 2 gives an idea of the kind of growth as well as the appearance of the boxes in which they grew.

The control yield for rye was very low, only treatments 9 and 4 (containing sewage and sawdust) yielding lower results. Treatment 7, which contained 2.5% hen manure and 97.5% soil (no compost), yielded the largest dry weight, and was highly significant above the control. Treatment 6, in second place, and significant to the 5% level, contained 2.5% hen manure, 22.5% sawdust and 75% soil. On the other hand, treatments 13 and 14 produced yields with this crop which were significant at the 1% level[6] above the control. This response from treatment 13 is consistent with its placement at the top on the basis of the general summary in Table 1.

The results with beets showed general agreement with this in placing yields from treatments 13 and 14 near the top. Yields from treatment 19 were largest of all with this crop for both tops and roots, significant above controls at 1% level for tops and 5% level for roots.

There are several general conclusions that may be drawn from Tables 1 and 2 in which seven sets of yield data are collated. Outstanding is the fact that mixtures containing hen manure, in general, produced the higher yields. Hen manure, again as in previous experiments, was a good agent for decomposing wood waste. The relatively high standing with treatment 16, originally containing fresh grass silage, shows that chopped green vegetation is also a good composting agent.

[6] Note: for readers not familiar with the term "significant at the 1% level", it means that the probability is very good that the difference shown is valid, i.e., there are 99 chances in 100 that the difference is a real one. "Significant at the 5% level" means 95 chances in 100, but the results are not quite so valid.

Table 1.—RELATIVE CROP RESPONSES FROM COMPOST MIXTURES IN OUTDOOR BOXES

Mixtures	Yield position (on basis of 7 crops)																		Accumulated position totals[1]	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
13	1	2	1		2			1												26	
19	2	1	1		1					2										32	
16	1	1	1	1		1		1	1											33	
6	1	2				1	1		1		1									38	
7	2			1	1			1				1	1							44	
2			1			1	2	1		1						1				57	
17		1	2						1				1	1		1				60	
18				1		1		1	1	1	1			1						62	
5					1	1		2			1	2								62	
14				2	1	1					1			1				1		63	
1					1		3						1		1	1				70	
10, 20				1				3						1		1	1			78	control
15			1								3	1			1	1				79	
12					1					2		1	1	1	1					80	
3				1						1	1	1			1	1	1			85	
8													2	2	2	1				100	
9									1								3	2	1	116	
11													1		1		3		2	117	
4																	1	3	3	128	

[1] Example: for Mixture 13, 1+2+2+3+5+5+8=26.

Table 2.—SEQUENCE OF EXCELLENCE OF CROP RESPONSE FROM COMPOSTS AND OTHER MIXTURES IN OUTDOOR GROWING BOXES

Mixture No.	Composition of growing medium		
	% compost	Make-up of compost or other material	% soil
13	25	25% hen manure, 75% shavings	75
19	25	25% hen manure, 75% shavings, 5% ground limestone	75
16	25	50% silage, 50% shavings	75
6	--	2.5% hen manure, 22.5% fresh sawdust	75
7	--	2.5% hen manure	97.5
2	--	0.1% Krilium	99.9
17	25	5% fertilizer 5–10–10, 90% shavings, 5% ground limestone	75
18	25	25% cow manure, 70% shavings, 5% ground limestone	75
5	--	2.5% sewage	97.5
14	25	⅓ silage, ⅓ shavings, ⅓ horse, hen, and cow manure	75
1	--	25% rotted sawdust	75
10, 20	--	Control	100
15	25	25% horse manure, 75% shavings	75
12	25	25% cow manure, 75% shavings	75
3	--	2.5% sewage, 22.5% sawdust	75
8	--	6.25% sewage, 18.75% sawdust	75
9	--	25% sewage, 75% sawdust	--
11	25	100% birch shavings	75
4	--	10% sewage, 90% sawdust	--

Inorganic fertilizer was a poorer composting agent than hen manure or silage (treatment 17). The composts or mixtures containing sewage produced very low yields, as did the compost of pure shavings in soil mixture treatment (11). Probably this was due chiefly to lack of nitrogen in the compost and shortage of nitrogen in the culture boxes. There was very little decomposition of the pure shavings while they were in the pit.

Plants grown in treatment 2, which consisted of Krilium and soil, yielded in 6th place in comparison with plants in other treatments, so Krilium did better as a soil improver than some compost mixtures, but poorer than others.

The foregoing statements verify the work by Baker and Dunn (2). The addition of 3 more sets of yield data did not much change the general sequence of excellence in yields with this series of culture. The use of these outdoor boxes for growing plants seemed to be a satisfactory method for testing composts and related materials.

2. Greenhouse pot cultures with sawdust composts from outdoor bins.

The general method of construction of the bins can be seen in Fig. 1. Hen manure, green material, and sewage served as composting agents. The mixtures of materials were as follows: Bin 1. 75% sawdust, 25% hen manure; Bin 2. 85% sawdust, 15% hen manure; Bin 3. 85% sawdust, 15% hen manure, 20 pounds superphosphate; Bin 4. 50% sawdust, 25% hen manure, 25% chopped green clover and grass; Bin 5. 50% sawdust, 25% hen manure, 25% chopped clover and grass, 20 pounds superphosphate; Bin 6. 90% sawdust, 10% sewage sludge.

The material, manure or otherwise, was very intimately mixed with the sawdust. The fresh hen manure was placed in a large, shallow, metal-bottomed mixing trough, along with an equal amount of water, and stirred with a garden hoe until it was of a thick "soupy" consistency. The sawdust then was added and mixed thoroughly with it. Similar methods were used with the other materials.

About a year later the contents of each bin were thoroughly re-mixed. Six months later than this, or eighteen months after starting these composts, samples were taken for nutrient analysis and for some greenhouse pot cultures with plants. The composts were mixed with soil in 20 to 80 proportion. Plants growing in soil only (without any added organic matter) served as controls. Each set of cultures was adequately fertilized before planting. Six different crops in two groups

of three successive ones, were grown in them. A description of these cultures, as well as results from them were given by Baker and Dunn (2).

Since then, six other crops were grown in these composts, in comparison to soil only as a control: radish, beans, and buckwheat, grown successively in 1-gal. size cans; corn, tomatoes, and sunflowers, grown successively in 14-qt. pails.

The other crops now to be considered were: corn and rye, grown as 4th and 5th consecutive crops in the contents of the pails in the above series. Besides these, there were radish, rape and oats grown in pure compost (undiluted with soil) in cans, and a crop of carrots grown also in pure compost in pails. For the radish and carrots the tops and roots were harvested separately, so that eight more sets of data now can be added, making a total of 14 sets of harvest figures upon which to base a comparison. These are summarized in Table 3, in the same way as the results of the pit-compost experiments were arranged in Tables 1 and 2.

Table 3.—SEQUENCE OF EXCELLENCE OF CROP RESPONSE FROM SAWDUST COMPOSTS (14 CROPS)

	Yield Position of Bin							
Compost	1	2	3	4	5	6	7	Total
Bin 4	5*	8	-	1	-	-	-	25**
Bin 5	4	4	2	2	-	2	-	38
Bin 1	3	-	3	6	1	1	-	47
Bin 3	1	1	4	-	6	2	-	57
Bin 2	1	1	2	3	5	2	-	58
Bin 6	-	-	2	-	1	6	5	82
Control	-	-	2	2	-	1	9	83

*Number of times occurred in position 1.
**Example: for Bin 4, 5+16+4=25, the smallest total and thus ahead of the other six.

Contents of bins as they occur in yield position
Bin 4—25% hen manure, 50% sawdust, 25% green material.
Bin 5—25% hen manure, 50% sawdust, 25% green material, 20 lb. superphosphate.
Bin 1—25% hen manure, 75% sawdust.
Bin 3—15% hen manure, 85% sawdust, 20 lb. superphosphate.
Bin 2—15% hen manure, 85% sawdust.
Bin 6—10% sewage sludge, 90% sawdust.
Control—Soil only.

To further aid in evaluating the relative standing of these compost treatments, the number of times the yields with each were significant above (or below) those of the controls have been tabulated in Table 4. Their standings in Table 3, plus the fact that the composts in bins 4 and 5 scored significantly above the controls at the 1% level 12 times out of a possible 14 indicate that these were the best and that they have outstanding potentialities in promoting plant growth. They both contained the green material, which along with hen manure, is very advantageous in decomposing sawdust. After three years the materials in bins 4 and 5 were decomposed to the extent where they had lost their identity and were black and friable.

Table 4.—FREQUENCY OF OCCURRENCE OF CROP YIELDS AT SIGNIFICANT LEVELS ABOVE (OR BELOW) CONTROLS (BASED ON 14 SETS OF DATA FROM 12 CROPS GROWN IN SAWDUST COMPOST MIXTURES)

	No. of times yield highly significant above controls	
Treatment	Highly significant (1% level)	Significant (5% level)
Bin 4	12	1
Bin 5	12	0
Bin 1	9	1
Bin 3	9	0
Bin 2	8	0
Bin 6	3	2
	Negative significance (below control yields)	
Bin 3	3	
Bin 6	3	
Bin 2	1	

Hen manure alone can do very well as a composing agent, as is shown by the standing of the compost from bin 1 (in 3rd place). The addition of superphosphate seemed to be of doubtful value, although it appeared to have some slight advantage in the compost with the smaller amount of hen manure, in bin 3 as compared to bin 2. Poorest of all the composts was that with sewage. Evidently, the sewage did not break down the sawdust very well and/or there were toxic materials present.

Again, there was very close agreement between these results and those of Baker and Dunn (2). This showed that this method and this type of bin was very satisfactory for handling and composting sawdust. It probably would do very well with other wood wastes.

3. Greenhouse pot cultures with sawdust composts from outdoor bins.

Soil, sewage, ammonium nitrate, and cyanamid acted as composting agents. It seemed desirable to secure more information about the composting effects of sewage, and of soil; the latter especially so, as it is readily available. Since both these were low in plant nutrients, additional nitrogen was supplied as ammonium nitrate. About two years after the start of the first six sawdust composts in outdoor bins as described above, two other bins, 7 and 8, were set up and filled. A year after that, bin 9 was filled with a mixture of sawdust, cyanamid, and superphosphate as recommended in "American Cyanagrams" (1).

The contents of these 3 bins were as follows: Bin 7. ⅔ sawdust, ⅓ dry sewage sludge, 14.4 lbs. NH_4NO_3; Bin 8. ⅔ sawdust, ⅓ soil, 14.4 lbs. NH_4NO_3; Bin 9. 100% sawdust, 13 lbs. Cyanamid, 15 lbs. superphosphate.

After the contents of bins 7 and 8 had composted for about 1½ years and that of bin 9 for about five months, samples were taken from each for tests with plant growth in the greenhouse. Two sets of cultures, one with buckwheat and another with radish were grown in mixtures of each at 30 percent compost and 70 percent soil, in comparison to soil only as control. Two other sets of the same crops were grown simultaneously in pure composts (undiluted with soil), along with a set of soil controls. All were grown in cans, and fertilized adequately at the start.

The results are summarized in Table 5. With only one crop, in treatment 3 (from bin 8, sawdust and soil compost) the yield was significantly greater than that of the control. In four other instances, the yields from the crops in composts were significantly less than the control yields. Three of the crops in composts from

Table 5.—SEQUENCE OF EXCELLENCE OF CROP RESPONSE FROM SAWDUST COMPOSTS—4 CROPS

	Yield positions				
Treatment	1	2	3	4	Total
4	1	3			7
3	2	-	1	1	9
2	-	1	3	-	21
1	1	-	-	3	13

Contents of treatments as they occur in yield positions—2 crops with pure compost and 2 with 30% compost and 70% soil
4—Control—soil only
3—⅔ sawdust, ⅓ soil, 15 lbs. NH_4NO_3
2—⅔ sawdust, ⅓ dry sewage slude, 15 lbs. NH_4NO_3
1—100% sawdust, 13 lbs. cyanamid, 15 lbs. superphosphate

bin 9 (sawdust plus cyanamid) produced very poorly. With one crop, grown in this compost mixed with soil, the yield was slightly better than that of the control. Apparently the time of composting here was too short to allow sufficient decomposition for good results. When this compost was diluted with soil the adverse effects were not so pronounced. In general, these summarized results indicate that none of these three methods are very good for composting, although the number of crops tested was relatively small and no crops were grown successively in these cultures. They might be worth further investigation.

4. Greenhouse pot cultures with sawdust composted by a bacterial accelerator

From time to time various aids to composting have been advertised. Usually they are said to contain cultures of microorganisms which are supposed to speed up decomposition of waste materials. One such was "Activo," a so-called bacterial accelerator. A trial of this on a small scale was made in various mixtures of sawdust. It was recommended that the Activo be mixed with an equal amount of soil and then aded to the compost. This was done at a higher rate than the recommendation of one pound p

:00 of compost, because the manufac-·rer stated that extra material did no :rm, and wood waste is known to ·eak down with difficulty.

The composts were placed in large ·ooden tubs, of about three or four ·bic feet capacity, outside the green-use, and contained the following .terials: Tub 1. 100% sawdust, 800 .ms limestone, 275 grams Activo; ·b 2. 33% green grass, 67% saw-·t, 200 grams Activo, 600 grams ·estone; Tub 3. 33% green grass, % sawdust, 600 grams limestone; ·b 4. 25% hen manure, 75% saw-·ust, 800 grams limestone, 275 grams Activo; Tub 5. 25% hen manure, 75% sawdust, 800 grams limestone; Tub 6. 100% sawdust.

Fresh softwood sawdust was used. The green grass was one-day old lawn clippings. The hen manure was fresh and undiluted. The composts were started early in May and kept moist by hose from the greenhouse until October. At this time, about five months after starting the composts, samples were taken for pot cultures in the greenhouse. They were mixed in proportions of 30 percent compost to 70 percent of soil by volume and placed in cans, 10 cans per treatment. Soil only was used as control, and all cultures were fertilized adequately before each crop. Three crops were grown, corn, cabbage and buckwheat, successively.

The yield results have been summarized in Table 6. With the corn crop all of the yields in the compost mixtures were greater than that from the control by high significance, 1% level. There were no significant differences in the yields for cabbage. With buckwheat, the yield from plants grown on treatment 3 (grass, sawdust, limestone) was significantly higher than the control, and treatment 6 (pure sawdust compost) gave yields less by high significance.

As to the general standing of these treatments on the basis of Table 6, while treatment 2, containing Activo, was slightly better than treatment 3, like it in every respect except for the had considerable effect on the higher yields in treatment 2. The benefits from this have been amply demonstrated in previous experiments. In the composts with hen manure and in the pure sawdust there was no benefit from the Activo.

On the basis of these three crops the bacterial accelerator Activo did not produce consistent promotional results. The green material and hen manure were apparently more influential in decomposing sawdust.

This is in agreement with the conpt voiced by Thom (8). He said that a dead cat will rot with the same organisms either above or below ground. If buried then, the rotting is still done by "dead cat organisms." Similarly, the rotting of wood waste may be regarded as taking place primarily by the organisms this material carries with it. These organisms may be aided in their growth to some extent by the nutrients in manure or other added materials, and also by the moisture from the soil or other phases of the environment. If this is true, inoculation with special organisms is not necessary.

Table 6.—SEQUENCE OF EXCELLENCE OF CROP RESPONSE FROM SAWDUST COMPOST WITH A BACTERIAL ACCELERATOR—3 CROPS

Treatment	Yield position 1	2	3	4	5	6	7	Total
2	1	1	1	-	-	-	-	6
3	-	1	2	-	-	-	-	8
5	1	-	-	1	1	-	-	10
4	1	-	-	1	-	1	-	11
6	-	1	-	-	-	1	1	15
1	-	-	-	1	1	-	1	16
Control	-	-	-	-	1	1	1	18

Contents of treatments as they occur in yield positions—each at 30% compost to 70% soil
2—33% grass, 67% sawdust, limestone, Activo
3—33% grass, 67% sawdust, limestone
5—75% sawdust, 25% hen manure, limestone
4—75% sawdust, 25% hen manure, limestone, Activo
6—100% sawdust
1—100% sawdust, limestone, Activo
Control—Soil only

Conclusions

These results suggest a number of conclusions as to methods of composting wood waste, materials to be used as aids to composting, and methods of testing such composts by plant growth cultures.

1.—The best method of composting was to place the mixtures of raw materials in a wooden bin, outdoors, but near a source for adding water as needed to the contents. Second best was that of placing the mixtures in outdoor pits dug in the ground.

2.—Both hen manure and chopped green vegetation were very effective aids to composting sawdust or shavings. The resulting composts produced best plant growth in comparison to any other material. Sewage, a bacterial accelerator, and many other materials, including other farm manures, were of poor or moderate value in this respect.

3.—Testing of the effectiveness of such composting methods and materials may be done very satisfactorily by means of plant response in either greenhouse pot cultures or wooden boxes for outdoor growth studies.

A Summary From a Practical Standpoint

This is an effort to answer some questions that may be asked about these results from a practical point of view.

Are the significant differences in favor of good plant growth with certain composts important enough to justify a sawmill man to try to compost?

ANSWER: Yes, with certain qualifications. He could try it out on a small scale, and determine if it would fit into his scheme of operations. Success with such a venture would depend upon many factors, such as labor costs, costs of crude lumber for building bins, availability of hen manure, salesmanship in building up a good market for the composted products, etc. One thing is certain, and that is that properly composted sawdust can be very beneficial to plant growth.

If the sawmill man has no hen manure available, should he forget the whole business?

ANSWER: By no means. There are other possibilities. It has been shown here that chopped green vegetation makes a good compositng agent for wood waste, although not as good as hen manure. Further, there are many possibilities in the use of sawdust or other wood wastes directly as a litter for poultry or other farm animals. There it would be mixed, and then could be either stored or used directly in soil applications.

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Scientific Timber Quality Evaluation—

A Lumber Industry "Must"[1]

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There are many possibilities for important savings in the utilization of raw wood material. The methods for obtaining increased value of woods products will undoubtedly come with the scientific analysis of timber stands and the logs they can produce. Though there are many aspects of this scientific analysis, its objectives would be, 1) to determine the probable occurrence of avoidable losses and miscalculations, and 2) to institute measures to reduce such losses. The lumbering industry as a whole would profit greatly from a log-grade system based on research. In fact, it is an industry "must."

THE LUMBER INDUSTRY is making strenuous efforts to improve its economic position, and, on the basis of scientific analysis, to improve practically all facets of its operations. The most spectacular progress noted is in mechanization of both extraction and conversion operations. The "hottest" field is that of merchandizing.

But what about the raw materials for this wide-spread industry? Are there opportunities for important savings here? If so, where do they lie and what is their magnitude? The purpose of this paper is to indicate an answer to these and related questions.

There is little nationwide research-based information on timber and log procurement. For example, how can purchase procedures be improved so as to give greater savings? Is log-making, as now practiced, wasteful or conservative of inherent values? What is the relation of log quality to subsequent operations? A thorough analysis of all aspects of timber procurement and log-making should be a vital part of any lumber-industry modernization studies.

It is well known that log procurement is complicated. Action lines for the operations between timber purchases and log sawing are indirect and unclear. Many people with different interests are involved. The situation in the West—where government stumpage is an important factor—is different from that in the East where it is not. Inherent local timber-quality variations differ widely between hardwood and softwood operations, between East and West. Therefore, because of the complexity of the subject and the limited basic information on which to draw, this paper considers only the eastern hardwood area, a region that produces nearly one-half of the nation's lumber and practically all of its hardwood—about 8 billion board-feet.

The industry knows the direction in which it must go in modernizing its conversion practices. At mill after mill throughout the region, costs are being reduced by the installation of labor-saving devices, by streamlining operations in general, by sawing more accurately, grading more closely, seasoning more scientifically, and utilizing mill residues more completely. The East will also play a large part in the industry's forthcoming marketing campaign.

Woods operations in the region are, for the most part, reasonably well mechanized and, as a result, the labor situation has been stabilized. In many areas, better transport has yielded the benefit of year-round instead of seasonal operations. Still, it is generally agreed that savings in this phase of the raw material field have accrued to workers or to stumpage rather than to conversion margins.

Offsetting the operational advantages gained by improvements is the fact that the price of stumpage has increased. Thus, in spite of modern mechanized logging methods, log costs have tended to rise. In many operations they are more than 50 percent of the total lumber-production costs. The major items of labor and stumpage will not drop, yet it is possible that additional means of lowering the cost of logs will be found.

And there is one promising area to which the industry can look for significant savings above and beyond log costs. This appears to be in methods of obtaining increased value of products from the raw material. The reference here is not to new products or new markets, through these will undoubtedly follow, but rather to a scientific analysis of timber stands and the logs they can produce.

The objectives of such an analysis will be 1) to determine the probable occurrence of avoidable losses and miscalculations that lower potential values and 2) to institute measures to reduce such losses. The basic tool needed for such an analysis and action program is a modern log-grading system.

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Log grading is not a new idea; hundreds of grading systems are used throughout the industry. But do these systems do the job that they are designed to do? Studies show that many not, that they are entirely too subjective, and limited, particularly in view of the quality variations in modern timber supplies. Many do not cover the full range of pieces physically capable of being sawed, do not have definite and stated objectives, and do not meet definite and stated performance standards.

Researchers in this field have found that objective systems can be developed that are precise enough to meet modern requirements. The development of such systems is essential if the raw-material and of the forest products industry is to be as sound technologically as the rest of the business.

Assuming that an adequate system of timber-quality evaluation can be developed, what are the possibilities of making savings through its use? There are four major places to look for savings: 1) timber-stand appraisal, 2) log-making, 3) log purchasing and selling, and 4) sawing control.

Timber-Stand Appraisal

It is generally recognized that the day of "walking and looking" timber estimates is over. Scientific sampling is required to obtain reliable stand-value estimates; this requirement stems from the wide variation in species composition, volume per acre, and timber quality.

Take timber quality: Recent studies of white pine indicate that, for one group of trees in the study (the poorest, ranging from 8 to 21 inches in diameter), the average value per thousand board feet of the lumber output was $90. For another group (the highest, with the same size range) it was $180 per M.b.m. And where 11-inch pine logs of the poorest quality yielded lumber worth less than $80 per M.b.m., 11-inch logs of the highest quality yielded lumber worth $240 per M.b.m. Published information on black cherry trees 22 inches in diameter showed lumber-value variation of from $80 to $130 per M.b.m. and for logs of identical size from $100 to $250 per M.b.m. (Veneer values, which run considerably higher, were not considered here.)

So the pattern of log grades must be determined if accurate per-thousand appraisal is to be made.

Furthermore, failure to use log-grade specifications can readily lead to serious over-estimates of volume in a given tract, because standard volume tables do not reflect grade of log. Such tables include anything that looks like log, whether it meets grade specifications or not. Over-estimates of volume not only affect returns to the owner or purchaser directly, but also indirectly because unit costs of improvements and supervision go up proportionately as volume goes down.

Log Making

Even though a concern has purchased a piece of timber and has estimated recoverable value and potential grade output accurately, the situation is by no means under control. Poor log-making can lead to significant loss of potential values. This occurs in two ways: 1) loss of volume and 2) loss of unit value.

Recent studies by the University of Michigan, the Central States Forest Experiment Station, and the Tennessee Valley Authority have shown a loss in oak and maple logging operations of log scale amounting to 6 to 20 percent of the potential cruised volume. Conservatively, an average loss from this source might be considered as 10 percent of average product value.

These same studies, plus one in Massachusetts and one in West Virginia, showed an additional average loss in expectable lumber output of over 10 percent from logs cut by unsupervised labor. Thus, the combined losses can readily be 20 percent of the potential. With average lumber value of $90 per M.b.m. for well-made logs, a loss of this magnitude would be $18 per M.b.m. Avoiding this loss would increase gross returns by $270 for a mill cutting 15 M.b.m. a day. If only half this loss were realized, and if, to get this half, it were necessary to pay for increased supervision of cutters, a savings of at least $75 a day might still be realized. Furthermore, by improving log quality, percentage of slow-moving low grades is reduced.

How well this scientific control system has worked is shown by an article on a southern mill in the September 1951 issue of LUMBERMAN magazine. This report states that in 1949 the company shipped 57 percent No. 2 Common and better hardwood and 43 percent No. 3 Common and worse. The concern then inaugurated a program of quality control in the woods based on the use of log grades. In ten months, shipments of No. 2 Common and better were up to 83 percent and No. 3 Common and worse were down to 17 percent. The average value of all shipments rose $15.86 per M.b.m. No data were given on volume increase.

How can control of this sort be exercised practically? The southern firm did it by grading logs in the trees and marking the cutting points on a blaze. Another way is to bring logs full-length to the woods or mill deck, where a log expert can mark them for cutting. Still another way is to instruct cutters and pay bonuses for better log-making. In any company, giving instruction in log grading to all the people involved in procurement will aid, not only in getting better logs, but also in improving other phases of the operation.

Log Purchasing and Selling

Competitive Aspect: It would be fine if log specifications were standard throughout the region, as are basic lumber grades, and if the only pricing differences were those derived from efficiency, location, or special factors (speculation, better bargaining, and so on). However, the industry must evaluate the cost to itself of confusing price quotations and inadequate specifications.

For instance, one man will pay $60 per M.b.m., Doyle scale delivered, for logs of a certain species that are "over 12 inches in diameter, well formed, of good quality, and free from bad defects." Another man will pay more or less per thousand for a 12-foot log of the same species that must have, according to specifications, three 4-foot clear cuts but no other required characteristics.

How can you compare prices under such circumstances? More important, how can such indefinite specifications be transmitted back to log makers, especially independent loggers, in an effort to increase quality of product yield?

Another problem is this connection is that of integration—selling portions of the woods run, either top end or residue. With good grading systems, buyers and sellers alike can make sound decisions on such important points.

Standard Pricing: If it is desirable to buy at one flat price, then a buyer can judge his average price either by judging the timber to be cut in a given period before hand, or by sampling the delivered logs for grade make-up. Log grade make-up may be critical. A study in West Virginia is a good example of what can happen. As cut on a commercial operation, a group of maple trees yielded 27 percent No. 1 logs, 51 percent No. 2 logs, 20 percent No. 3, and 2 percent below grade. If cut as they could have been cut, the yield would have been 51 percent No. 1, 36 percent No. 2, 13 percent No. 3's, and none below grade. The expected output on No. 1 Common and Better lumber of the logs as cut was 55 percent. Capturing this difference would have increased the value of average yields by $12 per M.b.m. and resulted in savings of $180 for a mill cutting 15 M.b.m. per day.

Evaluating Intake on Grade: With clear specifications, the grading of each

log at the mill or landing is the most scientific way of controlling the raw material situation. On stumpage jobs, cut grade can be checked against the estimated grade, and the required supervision can be supplied if there is too much difference. Price for purchased logs varies by log grade, and thus immediate control is gained since log grade is based on product output.

Sawing Control

Log Placement: Within the Forest Service, several studies are under way to determine the effect of log placement on the sawmill carriage: methods of placement for the several grades and also how the carriage affects placement on grade yields. Placement is gaged by the same factors used in grading the logs. These studies are not yet complete, but indications are that, if the log is initially placed in the proper manner on the sawmill carriage, value of output can be improved significantly. This possibility of saving may vary, of course, with log grade in that some grades may be more sensitive to this placement factor than others. There are indications in middle-grade hardwood logs that savings of 20 percent or better are possible by proper placement. If the good and poor logs are not sensitive to this factor, and if only a portion of the middle-grade logs are not sensitive to it, a savings on the total cut might well run to $5 per M.b.m., or about $75 per day for a small mill of the type commonly found throughout the East.

General Sawing: A pattern of log grade intake, if known, acts as a gage of the efficiency of the conversion process. It helps to estimate grade yield and can be used as an operating norm from which deviations can be detected and corrected.

Sawing Costs: In timber as found today, logs of all grades—except perhaps for very high quality prime logs—often have a restricted diameter range. To a large degree, sawing cost is a function of diameter. But it may also be a function of grade. This was indicated by a study in Vermont, where hard maple logs of four grades, all of the same size, were sawed, and the headsaw time was recorded. The following results were obtained:

Grade	Headsaw speed (feet per hour)
No. 1	1,400
No. 2	1,200
No. 3	1,100
Below	1,000

Thus, there was a difference of 30 percent in headsaw time between the poorest and the best grade logs in this test. Another test of graded logs with sizes running as they came gave results of 1,180, 960, 760, and 690 feet per hour respectively—an even greater percentage spread.

If these production rates are applied to the poor and good bucking patterns given above (27, 51, 20 percent yield vs. 51, 36, 13 percent yield) and a production cost of $40 per M.b.m. for the poor pattern is assumed, it is found that the improved grade pattern would have resulted in a production cost of only $37, and, thus would have saved $45 per day for a daily mill cutting 15 M.b.m.

Conclusions

There are many other aspects of scientific evaluation and control of raw material quality for making substantial savings. Through the practical application of log and tree grades, timber owners are aided in making decisions as to which trees should be left for future quality growth, which logs and trees are marginal, what the damaging effect of machinery on trees for growth is, and so forth. Log grades offer a means by which logs can be accurately sorted for the most profitable markets and for the cheapest conversion methods. All indications are that the industry and timber growers would gain in many ways if an objective, research-based system of timber-quality evaluation were developed quickly and applied intelligently.

Integrated Hardwood Logging

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In order to sustain the logger and the hardwood forests we must completely integrate the harvesting process. Fourteen distinct products, varying from 2 to 48 inches in diameter and from 17 inches to 40 feet in length, are obtained by Calumet & Hecla from northern hardwoods timber, principally hard and soft maple, yellow birch, and oak. The company employs two cutting methods in the sawtimber and second-growth stands: log length and tree length. The log length system has proved more desirable in the sawtimber stands

DURING 1957, 14 DISTINCT FOREST products were harvested from approximately 310,000 acres of forest land owned by Calumet & Hecla, Inc. in Northern Wisconsin and the Upper Peninsula of Michigan. These forest lands are managed on a sustained yield basis, assuring this company a continuing supply of logs and timber for its mines, sawmills, veneer plant, and dimension plants. Timber products not so utilized serve as raw materials for other manufacturers. This paper explains how these products are harvested.

Forest Description

A large percentage of Calumet & Hecla acreage is in northern hardwood timber, but in the Keweenaw Peninsula of Michigan nature defies ecology and we find balsam fir, white spruce, and northern white cedar intermixed and thriving with our hardwood species, hard and soft maple, yellow birch and red oak. Size classes range from saplings to overmature veterans.

Integrated Logging Defined

This vast acreage and species variety, along with the many varied products, poses many complex harvesting problems. Adding to these problems are ever-increasing costs of logging

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equipment and labor plus the decreasing attractiveness of logging chances. Integrated hardwood logging may be defined as the harvest, in one operation, of all the selected trees that will yield marketable forest products.

Before we can begin to log, however, we must have one other integration, that of the forester, the logger, and markets for our forest products. For without the wholehearted cooperation of the ingenious logger the forester can do very little and without markets both the forester and the logger have their hand tied. At times integrated hardwood logging is not possible because one particular product may be required at a specific time. Continuing forest products research, however, will keep the woods operation humming and in a healthy condition.

Preparing the Forest for Harvest

Manegement and logging plans for these forests are highly flexible and conform to the mold produced by market conditions at the moment. After having obtained the estimated needs of the utilization plants or a written order or contract specifying the desired products, the foresters prepare various descriptions for logging. Products taken from the woods vary from 2 to 48 inches in diameter and from 17 inches to 40 feet in length. First all ownership lines are run and double blazed. Then mature or defective trees are marked with blue or orange paint at breast height. Some trees receive a distinctive mark depending on the product to be cut, such as a horizontal paint line at breast height for smelter pole trees. Trees marked will, when removed, better the condition of the remaining stand but must also yield marketable products. Twenty inches DBH is used as a general guide in marking mature hardwood stands, although each tree is examined individually and either stands or falls depending on its condition, quality, and relationship to the surrounding stand. The average cut in sawtimber stands is 1500 board feet per acre of logs plus varied volumes of the other products. Marking in second growth stands improves the composition and quality of the remaining stand, and volumes removed are extremely varied. Let us consider the logging operation in two stages: 1) logging in sawtimber stands in which the greater volume is found in trees 12 inches DBH and larger, and 2) logging in second growth stands which have the greater volume in trees under 12 inches DBH.

Logging in Sawtimber Stands

Products produced from the sawtimber stands are veneer logs, mill logs, tie cuts, brake shoe logs, mine bumper logs, mine rollers, chemical wood and smelter poles. Some of these products are peculiar to the copper mining area and are described as follows:

1. Smelter poles—hard maple, soft maple, and birch, 28 to 40 feet long, reasonably straight, maximum butt diameter of 18 inches, minimum top diameter of 4 inches—used in the refining of molten copper. These are very low quality or essentially cull trees.

2. Mine rollers—hard maple, 12 inches minimum diameter inside bark, 17 inches long, not more than a 6 inch heart, turned down by lathe to 11½ inches by 15 inches—used in copper mine shafts to guide the skip cables so that the cable will not damage other shaft timbers.

3. Bumper logs—hard maple or oak, 12 feet long, 18 inches minimum diameter—used in the mine rock house to detain pieces of mass copper from going into the rock crusher.

4. Brake shoe logs—good quality basswood logs from which brake shoes are cut and shaped to be used on the large electric and steam hoists that raise the ore skip and man car from underground.

Two methods of logging are used: log length and tree length. The log-length method is the most common, with the tree-length method used only in conjunction with the log length for smelter poles. The log length has proved more desirable in our operations because of the generally short, crooked character of the Keweenaw timber and the very dense growth of sapling to pole size reproduction in the residual stands.

Planning: The key to success in any endeavor and the first step in the logging process is thoughtful planning. Head and leg work produce considerable savings to the logger as well as the mill owner. For instance, logging the most inacessible and difficult chances during the dry summer months and saving the closer, better chances for wet weather and winter not only assures the mill of a steady supply of logs but also keeps the jobber's pay coming in and his equipment working for a longer period of time. It helps the logger psychologically because he knows he has better going ahead. Shorter travel in the winter months also increase his productive working hours during those days of little daylight.

Gone are the days of the large logging camps. The typical operation now consists of six men daily who commute to the woods, 2 skidding tractors, and 2 trailer trucks. Horsepower has replaced manpower whenever possible and the woods echo with the noise of machinery.

Road Construction: An efficient road system is the heart of the logging operation. Before cutting commences, the summer roads are constructed, preferably a year in advance to let them settle and pack over winter. Road location and spacing are determined by topography and the location and density of the timber, but the typical logging chance finds approximately one road to 40 acres. Roads and skidways are planned so that, wherever possible, gravity aids in skidding and the loaded trucks haul downhill.

Spring is an excellent time for road layout and construction, visibility is good and trees are loose when the ground is wet. Culvert locations are readily apparent with the spring runoff. Winter road right of ways are bulldozed in the fall to avoid pushing snow around in winter. During the winter only enough road is built for the winter operations. If excess road is built in winter it will act as a ditch when the snow goes and will become muddy and take longer to dry out.

Sometimes in dense timber the trees on the road right-of-way are cut before bulldozing begins; a 3-foot stump is left for better bulldozer leverage. More commonly, however, the right of way is bulldozed without any prior cutting, and the bulldozed trees are later cut into the various products. Trees bulldozed from the right-of-way are, if possible, downed perpendicular to the road for ease of later sawing and to enable skidding machines to enter the woods at any place along the road. Tractors never operate or skid across the main haul roads.

Felling and Bucking: With the roads in place, sawyers begin their work of felling and bucking the trees into the appropriate products with one-man chain saws. Bulldozer trees along the roads are cut before the felling of standing timber commences.

Each sawyer is furnished a sheet setting forth all the current specifications of products to be cut and he is paid on a contract basis according to the value of the items. For instance, sawyers are usually paid from $1 to $2 per Mbm more for veneer logs than for mill logs. Chemical wood bolts, smelter poles, and butts are paid for by the piece. Chemical wood markets substantially increase the log production because sawyers are extremely hesitant to fell apparently unsound trees when they are paid only for the sawlogs they cut—but if they are paid for cutting the chemical wood they will tackle these doubtful trees.

The typical logger has two sawyers, one working on each side of the road.

Due to the scattered nature of the timber and the small crew, cutting strips are not necessary. Alternate loads are skidded from each sawyer and the sawyer is paid on the basis of the mill scale.

Skidding: All skidding is done with crawler tractors of the HD–5, or D–4 size. Logs are either ground skidded by tongs, chokers, or chains, or are arch skidded with a tractor mounted winch, an arch, and chokers. The average ground skidded drag consists of 300 board feet while 500 board feet can easily be brought in by use of an arch. Logging damage is directly proportional to the skill and care of the tractor operator instead of to the equipment used.

Arch skidding is advantageous in areas of dense reproduction because the skidding tractor does not have to back in close to the logs, but merely lets out cable to reach the previously chokered logs and then reels them in to the machine with little damage to the small trees. The maximum skidding distance is usually 2 tallies but may extend to 6 tallies in very difficult country or isolated patches of timber.

Smelter poles are ground skidded by tongs, and 2 or 3 poles are brought in at one time depending on their size. Mine roller trees are usually brought to the skidway in long lengths and there bucked into 17 inch blocks. Chemical wood is skidded in 7 to 9 foot lengths with 3 or 4 pieces brought in at a time.

Chokers are more desirable for skidding small products because there is less tendency for them to slip off of the log. Tongs must be used with care during the cold winter months as sudden jerks on logs frozen tight to the ground will break off the tips of the tongs.

Loading: Logs are loaded by use of either an A-frame jammer or a swing-boom jammer with a tractor supplying the motive power in either case. To load 8-foot material the cable between the "pups" is shortened by means of a hook. The 28 to 40 foot smelter poles are loaded with a swing-boom jammer and a pair of tongs which grip the pole near the balance point. Loading costs may be reduced with a low cost engine and winch jammer setup rather than the high-cost tractor cross-haul.

Hauling: The average logging truck is of the F–800 size, either tandem or not, with a 2-wheel trailer; it carries a log load of 2500 board feet. A typical haul is 35 miles, half over woods roads. Smelter poles are hauled on a trailer truck with an extended reach. There are 20 to 25 smelter poles per load with a total weight of 10 to 12 tons. Bob-tail trucks haul about 20 pieces of chemical wood per load. Some trailers are loaded in a piggy-back fashion for the return trip to the woods, to save wear and tear on the trailer as well as to increase maneuverability in the woods. Long-wheel-base tandems with a 4-wheel trailer behind are used successfully in level country to increase the pay load. More pay load per trip is the logical answer to the long haul—but the high cost keeps loggers from large trucks, while weight restrictions limit loading on medium-size trucks. Often a larger load of logs may be hauled on a small truck than on a medium-size one because of the lesser weight of the truck itself.

Logging in Second-Growth Stands

Products cut from second-growth stands include chute logs, stulls, chute poles, smelter brands, pulpwood, and cordwood. Again our copper mines have supplied some unique uses for wood and these products are described as follows::

1. *Chute logs*—hard or soft maple and oak, 12 feet long, 7 to 8 inch top, used underground to support the framework of a chute through which copper ore is loaded into cars.

2. *Stulls*—hard or soft maple and oak, 9 feet long, 8 to 10 inch top, used underground as uprights in the drift or used in batteries of three to support loose rock in stopes.

3. *Chute poles*—hard or soft maple, 10 feet long, 2 to 3 inch top, used underground to block the chute so that dirt and the copper ore does not go on the track.

4. *Smelter brands*—hard or soft maple and birch, 6 to 8 feet long, 3 to 6 inches in diameter anywhere on the brand, used as the final touch in the refining of molten copper.

In our ever-renewable second growth stands uitlization approaches the optimum, but all products are of a relatively low value. The growth rate is usually slow because of the density of the trees, and thinnings and improvement cuts are highly desirable. Cutting and skidding problems are multiplied because, in selection thinning, getting the comparatively light tree to fall to the ground in a dense second-growth hardwood stand is truly a problem. Many must be pulled down by the skidding tractor, increasing the work of both the skidding tractor and the sawyer.

The average crew in such stands consists of 2 or 3 men, a small tractor such as a John Deere, TD–6, or D–2, and a small truck. Most of these stands are readily accessible and old roads in these areas often need only to be brushed out and reconditioned. New-road development costs in these areas would usually make profitable logging operations impossible.

Whenever feasible, four or five products are harvested at the same time. After a tree is felled, marked off, and topped, it is long-length ground skidded to the skidway where for example, a 9-foot stull is cut from the butt, then a 12-foot chute log, then finally a smelter brand. If the tree is not large enough, only a 12-foot chute log and then a brand, or just brands or pulpwood will be cut from the tree. Often the tops are cut up for fuel wood. If only brands or chute poles are produced at one time, they are cut and hand loaded in the woods on wooden drays and then pulled to the skidway where they are loaded on trucks with the use of bunching chain and an A-frame jammer. Sometimes a front-end loader on a farm tractor is used for small operations.

Second-growth hardwood stands present many difficult problems both in management and harvesting but hold a tremendous potential as perhaps the largest raw material manufacturing plant in the world—one which certainly should be further investigated and utilized.

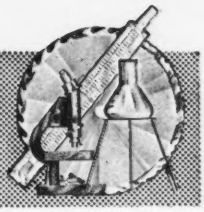
Conclusion

Great strides have been taken in the management of sawtimber and second-growth hardwood stands, so that at present they hold promise of producing a multitude of products in perpetuity. The logger, however, is faced with problems of increasing costs, greatly restricted logging under more intensive forestry, and lower value material on tougher chances over longer hauls. For mutual benefit, forestry must be closely coordinated with logging if maximum volumes are to be grown and utilized.

With existing markets, a large percentage of the total cubic volume of cut trees remains in the woods in the form of stumps, butts, branches, and twigs, to be utilized by nature in enriching the forest soil. Research and experimentation will continue on every phase of the management, harvesting and utilization of our vast hardwood resources.

One fact is evident: the future of our Lake States logging is dependent on the complete integration of the harvesting process. Let's take the whole tree out of the woods to the manufacturing plant—mother nature can have the leaves—maybe!

Abstracting the Literature



Debarking

Sucksdorff, Björn. Log soaker doubles barking. Pulp & Paper International 1, no. 1: 37–40 (Jan., 1959).

A new log-presoaking apparatus has played a major role in double barker output at the Kuusankoski, Finland mill of Kymmene AB. The apparatus comprises a hot-water tunnel through which the logs are carried by an upside-down conveyor. The pretreatment actually causes half the bark to fall from the logs; barking output was doubled without increasing manpower requirements and with a reduction in power requirement. The pretreatment apparatus never clogs, heat loss is small, steaming at the end of the tunnel is slight, wood losses are greatly reduced, and there are no broomed ends to the logs delivered by the apparatus. The article is similar to the earlier reference. 4 fig. [A.B.I.P.C. 29: 10]

Wood Waste Utilization

Block, S., Tsao, G., and Han, L. Production of mushrooms from sawdust. *J. Agr. Food Chem.* 6, no. 12: 923–7 (Dec., 1958).

This work was aimed at determining how effectively sawdust, bark, bagasse, and other cellulosic wastes might serve as a compost for mushroom production. Various types of mushroom were cultivated on sawdusts of pine, balsa, gum wood, and other materials, fortified in some cases with soybean meal or oatmeal. Yields were found to be low on a square foot basis, high on the basis of pounds of sawdust used per pound of mushrooms produced. In addition, the sawdust offers certain economic advantages over conventional compost materials. 6 tables, 4 figs., 20 refs. [A.B.I.P.C., 29:9]

Wood Properties

Nakato, K. On the cause of the anisotropic shrinkage and swelling of wood. XII. On the relationship between the microscopic structure and the anistropic shrinkage in transverse sections. (5). *J. Japan Wood Research Soc.* 4, no. 6: 205–10 (Dec., 1958). [In Japanese; English summary] *cf.* A.B.I.P.C. 29: 1052.

Earlier studies on the restraining action of wood rays on the radial shrinkage of wood disclosed the following facts: The microfibrillar orientation of wood rays makes it possible for them to restrict radial shrinkage. The shrinkage of wood rays is greater perpendicular than parallel to the longitudinal axis of the ray cell. The restraining action can be recognized through observations of thin sections having a regular distribution of wood rays. The present study dealt with the effects of fine and broad rays on the radial shrinkage of sugi. *(Cryptomeria japonica)* spring- and summerwood, momi *(Abies firma)*, karamatsu *(Larix kaempferi)*, and mizunara *(Quercus crispula)*. Detailed results of this study are given. 3 tables, 6 figs., 11 ref. [A.B.I.P.C., 29:9]

Woods Safety

Anon. An effective approach to woods safety. Northeastern Logger 7, no. 7: 14–15, 30–1 (Jan., 1959).

A description is given of the safety program instituted at the Woodlands Division of the Scott Paper Co., a program which resulted in reducing the accident frequency by 34% from 1954 to 1958 and in reducing accident severity by 62% over the same period. The success of the program is attributed to the development of a good safety attitude in each employe by means of a detailed safety organization, enthusiastic top management support, and constant day-to-day safety efforts by every supervisor. 1 table and 6 figures. [A.B.I.P.C. 29: 10]

Bark Utilization

Price, F. A. Bark and refuse pile turned into economic asset. Pulp Paper Mag. Can. 60, no. 1: 80–5 (Jan., 1959).

The new bark-burning boiler recently put into operation at the Three Rivers, Que. mill of St. Lawrence Corp., Ltd. had to be designed to burn processed bark, oil, or coal. The bark handling, processing, and burning were designed to be an 8-month operation— months during the barking season and 2 additional months until the mill's 2-yr. ac- The desig nof the boiler and furnace and the reclaiming and processing operations are described. 1 figures [ABIPC 29: 10]

Hardboard

Kumar, V. B. Application of statistical quality control methods to thickness analysis of hardboard. Part 2. *Svensk Papperstidn.* 61, no. 21: 922–5 (Nov. 15, 1958). [In English; Swedish and German summaries] *cf.* A.B.I.P.C. 29: 858.

Thickness variations in hardboards were analyzed. Boards obtained from the three uppermost daylights of a press showed the lowest probability of acceptance, whereas boards from the central and lower daylights were usually uniform throughout and likely to be accepted *in toto*. Quantitative data on acceptance and rejection are presented. 1 table, 4 fig. 3 refs. [A.B.I.P.C., 29:8]

Chip Storage

Holekamp, J. A. Progress report on the outside storage of southern pine chips. *Paper Trade J.* 142, no. 49: 36–8 (Dec. 8, 1958).

Some information available on wood deterioration in outside storage, chip contamination, types of handling equipment, costs of transporting chips to and from storage, and storage volumes per acre for chips *vs.* roundwood sticks is presented. 4 tables, 4 figs. [A.B.I.P.C., 29:8]

Pulping

Brown, Kenton J. Cold soda pulping of southern oaks, sweetgum, and cottonwood. Tappi 42, no. 2: 158–64 (Feb., 1959).

Batch and continuous cold soda pulping methods were used to pulp several southern hardwoods. Pulping characteristics were determined, and the properties of pulps made from these woods were compared. A mixture of two red oak species, water oak *(Quercus nigra* L.) and willow oak *(Q. phellos L.)*, was pulped under various conditions of pressure, time, temperature, and chemical concentration to produce pulps having yields in a range of from 82 to 96%. Pulp strength was increased by increasing the time, temperature, or pressure of the caustic soda treatment. Increasing the caustic concentraiton above 35 g./liter lowered the yield and brightness of pulp made at room temperature but had little effect on its strength, which was slightly above that of softwood groundwood. The brightness of pulp bleached in a single stage with 10% available chlorine in the form of calcium hypochlorite decreased about 5 percentage points as the caustic soda steeping temperature was increased in a range of from 25 to 89° C. Pulp suitable for use in printing paper as a substitute for southern pine groundwood was made by treating a mixture consisting of several hardwoods, including red and white oaks, gums, and poplar, with caustic soda solutions at room temperature in a digester for either 2 hr. at atmospheric pressure or 30 min. at 150 p.s.i. Sweetgum *(Liquidambar styraciflua)* cold soda pulp was slightly stronger than southern pine groundwood, but darker in color. Cold soda pulp made from cottonwood *(Populus deltoides)* was somewhat stronger and lighter in color than sweetgum cold soda pulp. Corrugating boards produced from cold soda pulps made in the continuous system from mixtures of water oak and willow oak and of red oak and white oak had Concora values of 54.1 and 51.3 lb., respectively. A somewhat stronger board made from cottonwood cold soda pulp had a Concora value of 77.4 lb. 6 tables, 3 figures, and 4 references. [A.B.I.P.C. 29: 10]

The preparation of abstracts from the world literature is so highly specialized and costly that the Forest Products Research Society has no abstracting service of its own. For the abstracts used in the JOURNAL the Society is indebted to the respective abstract journals indicated, from which they have been selected with the kind permission of the editors. Readers wishing information in addition to that given in these abstracts should consult the original articles. Copies or additional information can not be supplied by FPRS or the abstract journal.

BRI ABSTRACTS OF BUILDING SCIENCE PUBLICATIONS, published for the use of its members, by the Building Research Institute, National Academy of Sciences—National Research Council, 2101 Constitution Avenue, Washington 25, D. C.

BULLETIN OF THE INSTITUTE OF PAPER CHEMISTRY, published monthly at Appleton, Wisconsin, by the Institute of Paper Chemistry.

CHEMICAL ABSTRACTS, published semimonthly by the American Chemical Society, Executive Office—1155 Sixteenth Street, NW, Washington 6, D. C.

TECHNICAL BULLETIN OF THE FURNITURE DEVELOPMENT COUNCIL, published bimonthly by the Council at 11 Adelphi Terrace, London W. C. 2, England.

Shimoda, Isao, and Shindō, Akhiro. Studies on chemi-groundwood pulp. On the behavior of neutral sodium sulfite solution, its penetration into various woods, and its penetration time. J. Soc. Textile and Cellulose Inds., Japan 14, no. 5: 282–7 (May, 1958). [In Japanese; English summary]

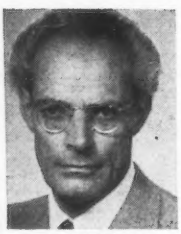
The penetration of sodium sulfite solution into three softwoods (spruce, white fir, and red pine) and eight hardwoods (poplar, lime, birch, alder, itaji, scaber, beech, and oak) was investigated under three different conditions, viz., at 15–20° C. and normal or reduced (0.5 atm.) pressure, and at 140° C. under 12 kg./sq. cm. pressure. Reduced pressure at room temperature facilitated penetratian. Under pressure at high temperature, 80-mm. long wood samples were penetrated completely within 25 min., indicating that logs 75–90 cm. long can be impregnated to the core in 6–8 hr. 2 tables, 5 figures, and 3 references. C.L.B.

Helge, K. Utilization of stored, dry wood as raw material for porous wood-fiber boards. *Norsk Skogind.* 12, no. 10: 371 (Oct., 1958). [In Norwegian; English summary]

The increasing demands posed on the quality of fiberboards have placed similarly high demands on the quality of the raw material, particularly for insulating board. The use of stored (seasoned) wood impairs the water resistance, dimensional stability, and color of porous building board and gives lower yields while requiring a higher power consumption in grinding or refining the chips than does green wood. On the other hand, fiberboards made from dry and green wood chips refined to the same degree of freeness show equivalent specific gravity and strength properties. The difficulties encountered in fiberizing stored wood are attributable largely to changes which occur on prolonged outdoor seasoning; these effects cannot be reproduced by accelerated laboratory drying. 6 tables, 1 figures, and 1 reference. [B.I.P.C., V. 29, No. 6]

WORLD-WIDE Forest Products News

DR. COTE



DR. MARION

California Wood Technologist Will Leave for India

Dr. Joseph E. Marion, Forest Products Laboratory, University of California, will take a year's leave of absence to serve as consultant on forest products in India. His appointment, officially that of advisor to the National Council of Applied Economic Research of the Government of India, has been confirmed by Dr. P. S. Lokanathan, Director General of the Council.

Dr. Marion's duties are expected to include a series of techno-economic surveys of various Indian states having to do with the utilization of forest products in industry.

Syracuse Faculty Member Awarded Research Fellowship

Dr. Wilfred A. Côté, Jr., assistant professor of wood technlology at Syracuse University, has been awarded a Fulbright Post–Doctoral Research Fellowship for study and research abroad during the 1959–60 academic year. He is scheduled to depart for Europe this September.

Dr. Côté, a specialist in electron microscopy, will do advanced research in electron microscopy of wood structure at the Institut Für Holzforschung und Holstechnik (Kollman Institute) of the University of Munich.

Advisor to Pakistan Forest Products Laboratory

Dr. A. C. Barefoot, North Carolina State College, Raleigh, has been appointed by I.C.A. veneer and plywood advisor to the Pakistan Forest Products Laboratory, Chittagong, Pakistan.

Dr. Barefoot left for Pakistan in midsummer and as a result vacated his chairmanship of the Forest Products Research Society Quality Control Division.

New Books; Literature

Catalogue of Portable Wood Chippers, Forest Equipment Notes, D. Cat. 2. Food and Agricultural Organization of the United Nations. Prospects discussed, manufacturers listed. Technical specifications in table form. English and French. 28 pp., illustrated. Write FAO, Vialle delle Terme, Rome, Italy.

Saw Files and Saw Filing, Forest Equipment Notes, D. 22.59. Food and Agricultural Organization of the United Nations. A guide to files for wood cutting blades. Dimensions, tapers, and terminology. 7 pp., illustrated. Write FAO, Vialle delle Terme, Rome, Italy.

Encyclopedia of World Timbers. This new edition by F. H. Titmuss describes briefly the structure, characteristics, and uses of nearly 200 kinds of timber. Photomicrographs have been added illustrating 30 kinds of wood. 264 pp. Published at $15.00 by the Philosophical Library, Inc., 15 East 40th Street, New York 16.

Forest Machinery. An account of various machinery, its application and operation in forestry and woodland maintenance, and the economic considerations involved. Illustrated. The authors, E. R. Huggard and T. H. Owen, are in the Department of Forestry, University College of North Wales. Published at 24s by Adam and Charles Black, 4,5, and 6, Soho Square, London, W.1.

Forestry and Timber Technology. A catalog of books available at Stobart and Son, Ltd., 29 New Bridge Street, London EC4. Other lists available on allied subjects.

Production of Poplar Timber in Europe and Its Significance and Application in the United States. Agricultural Handbook No. 150. USDA, Foerst Service. Author is Ernst J. Schreiner, in charge, Forest Genetics Research, Northeastern Forest Experiment Station. 128 pp., illustrated. Write Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Price, 45 cents.

Other Developments Around the World

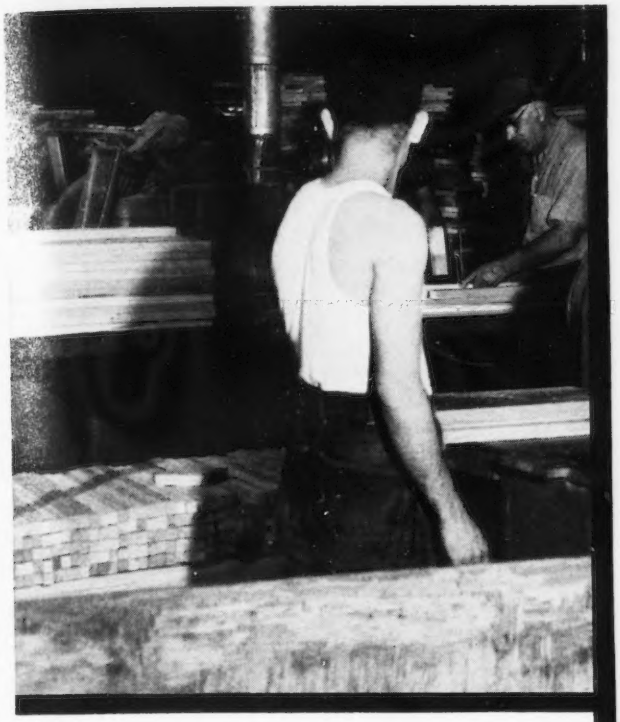
● Australia

Sawing Those Difficult Timbers. D. S. Jones. *Forest Products Newsletter,* No. 240, April, 1958.

Sawing research was done on some difficult Australian hardwoods by the Division of Forest Products, C.S.I.R.O. Of the timbers studied, brush box *(Tristania conferta)* was most difficult to saw.

Good results were obtained by reducing the saw speed from the usual 10,000 fpm to 7,000 fpm, but maintaining the tensioning of the saw for the higher speed. The slower saw speed was beneficial for all timbers. It increased saw stability and dimensional accuracy of the sawn product. The life of the saws between sharpening was also increased, and consumption of electricity was reduced. Consequently, with additional power available, difficult cuts could be made more quickly and easily, with a reduction in production time.

The general conclusion was that when working with a timber that is difficult to saw, a reduction of the rip speed should be beneficial.



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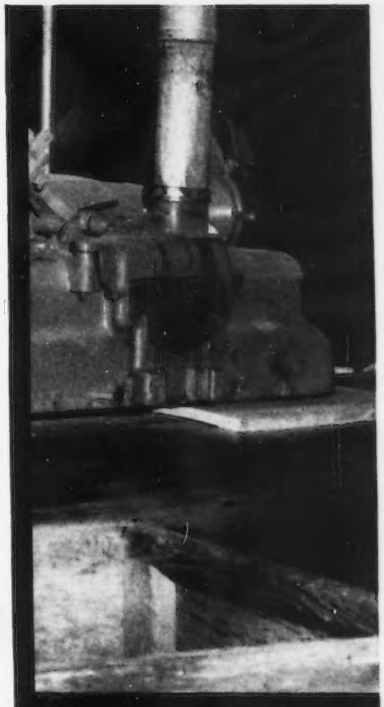

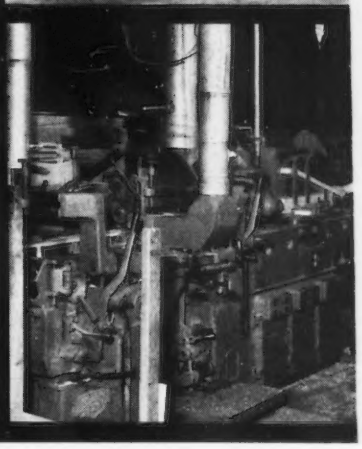

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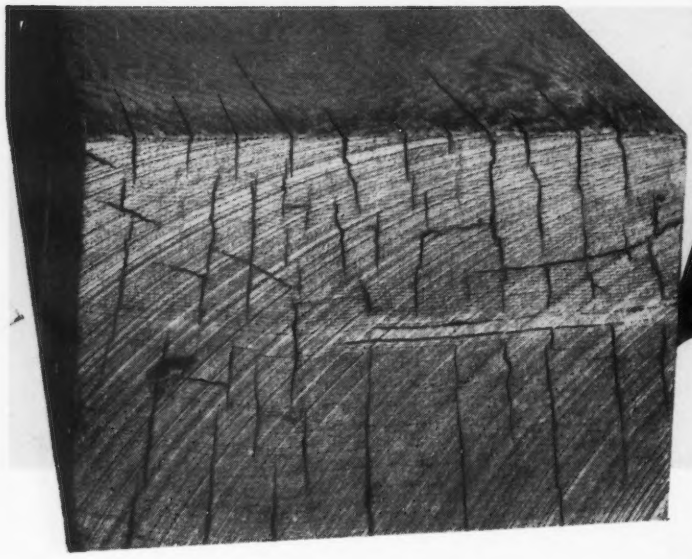

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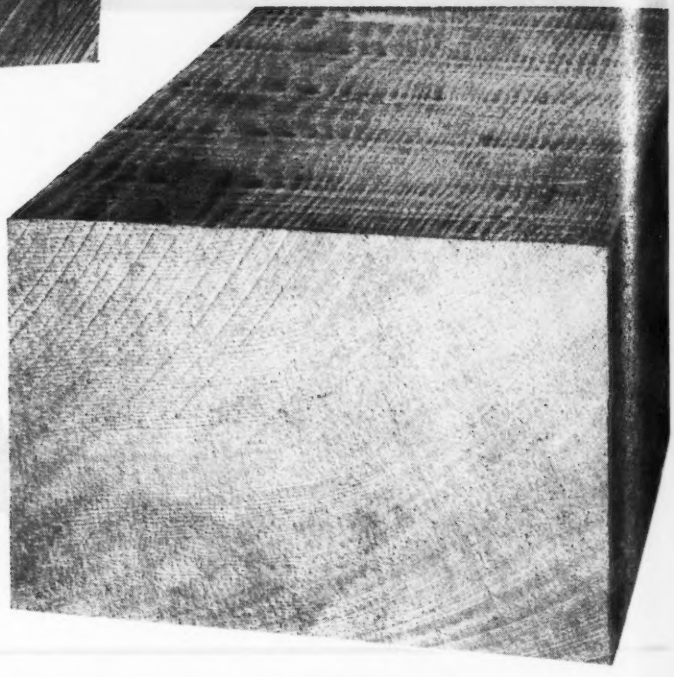

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